various untoward influences. In granular kidney it responds first by athero-sclerosis of its intimate inter-visceral twigs; secondly, at a later period, when not these vessels but the systemic trunks suffer under another influence, under the stress, that is, of excessive pressures, the vessels again make the only response of which they are capable; they express their reaction to a different injury also in similar terms of arterio-sclerosis. Leaving now kidney disease and turning to the series which Huchard called "Presclerosis"—my Hyperpiesis—a series in which as yet the kidneys have not been convicted of complicity, we may find again arterio-sclerosis; but only after the mode which in Granular Kidney affects the arteries of large and middle magnitudes under tensile strain, a secondary, and often preventable result. To the arterio-sclerosis of Hyperpiesis the kidneys, so far as yet known, stand in no correlative relation.

But there is yet another arterio-sclerosis, or, at any rate, an arterio-sclerosis found in quite another category—namely, the arterio-sclerosis which in 1894 I separated as the senile or decreescent form. Whether it is histologically identical or not with the kind of which we have been speaking is as yet an open question; but clinically it is distinguishable, as it arises independently of high arterial pressures, or, at any rate, under pressures not excessive for the time of life. Now in this mode of arterio-sclerosis the kidney is often altered, perhaps always, more or less. This alteration, which, again, usually puts on the shape of a shrunken or deformed kidney, has little pathological affinity with the granular kidney which it may simulate. Besides the granular kidney which goes wrong with an intimate arterio-sclerosis of its own, there is a kidney deformed in the course of a general arterio-sclerosis not its own, and if more or less decaying in consequence of decay of its nutrient arteries, yet without any original perversion. A starved but not a corrupt kidney. This form some of us have long tried to differentiate, being disposed to see in it rather a negative state, a state more or less inadequate in regard of margin of safety, but sufficient for the smaller life of an elderly man. Dr. Sainsbury has emphasized "the marvellous residual vitalities of damaged organs." This kidney contains islands of fairly normal renal tissue sufficient for the humbler sphere of life, by which I was disposed to contrast it with the true granular kidney, which I had regarded as necrobiotic all through. But so sharp a contrast cannot quite be maintained; in the granular kidney, also, there are islands of fairly normal tissue, and the essential difference seems as yet to lie, not within the compass of the kidney, but—as we have surmised—in some poison at the back of the kidney and the arterial disorder alike. However this may be, the two kinds of kidney, often similar in aspect, at any rate superficially, are radically different in nature—a difference which, if hardly to be recognized in an effete organ, yet in the clinical series to which it belongs is, in uncomplicated cases, unmistakable. And in this distinction, as my citations have proved, I am far from standing alone.

Professor Lorrain Smith's conclusion in our joint paper was accordingly, that the arterio-sclerotic kidney is a local phase of general arterial disease, producing in the kidney just the alterations which it produces in other organs of the body—alterations which need not amount to anything very grievous, as they are compatible with many, if sore and yellow, years of life; but that granular kidney, on the other hand, is some form of progressive inflammation of the gland as such, the structures essential to its function being attacked. In this fatal disease arterio-sclerosis appears in two ways—primarily and essentially in the fine arterioles of the organ itself; secondarily and later in the systemic arteries, as the effect of strain under the excessive arterial pressures in which granular kidney is always and regularly involved. The arterio-sclerotic kidney, on the other hand, if it may arise in the later stage of strained arterial systems in Hyperpiesis, is most common in the decreescent form of arterio-sclerosis.

If I may formulate these provisional conclusions, they would be as follows:

CLASS A.—Chronic Bright's Disease.

A (i). Primary intrinsic intrarenal arterio-sclerosis not due to high pressures; in granular kidney constant; in other kinds inconstant.

A (ii). Secondary extrinsic arterio-sclerosis; later; due to high pressures.

A (iii). A few mixed cases; renal disease supervening on a general arterio-sclerosis, whether of "Hyperpiesis" or "Decrescence"; not originally Bright's disease.

CLASS B.—Not Bright's Disease.

B (i). The "arterio-sclerotic kidney"; kidney alteration secondary to general arterio-sclerosis, more frequently of the decreescent kind without high pressures.

B (ii). Less frequently, entailed by the consecutive arterio-sclerosis of "Hyperpiesis."

High pressures may be considered as (i) obligate with Granular Kidney; (ii) irregularly associated with other kinds of Bright's disease; (iii) independent of Bright's disease ("Hyperpiesis").

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ON THE INTERDEPENDENCE OF THE CIRCULATORY AND RESPIRATORY SYSTEMS.

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THE factors which contribute to a fatal issue in acute lobar pneumonia are very difficult to estimate. The infected patient is subjected to the adverse influences of a complicated series of abnormal processes, which, for the sake of convenience, may be termed chemical and mechanical. The chemical agencies probably include the disintegrating bacteria, the local products of the reaction between the micro-organisms and the host, and various other substances of abnormal quantity or quality which originate as a result of the interference of toxins with the normal metabolism in parenchymatous organs. These processes manifest themselves in well-recognized anatomical changes in the liver, the kidneys, and the cardiac muscle, and the clinical manifestations of the disease indicate a reaction on the part of the nervous system also. The degree to which the parenchymatous organs are affected depends on the amount of abnormal chemical substances present, and the affinity of these for the affected organs. The progress of the disease will be determined largely by the reaction of the bone marrow and other tissues which supply the antistances necessary to hold the noxious chemical processes in check. The issue of pneumonia, however, may be influenced by the variation in mechanical conditions incident to the disease. The pain of the pleurisy interferes with free movement of the chest wall, and an extensive consolidation, too, limits the expansion of the thoracic cavity and creates an obstruction to the pulmonary circulation. The work of the right ventricle is thus increased, and if the cardiac muscle be affected the efficiency of the organ may be seriously prejudiced.

In the case of those conditions which are classed collectively as bronchopneumonia in children, the mechanical difficulties are often very pronounced. Rapid respiration and cyanosis are common features of bronchitic affections, accompanied by rickets and atelectasis. In many of the cases the toxic effects of the pneumonia are much less serious than the physical disability under which the heart suffers in maintaining the circulation. An extensive clinical and correlated *post-mortem* experience has established this fact beyond all doubt.

Within very narrow limits the healthy heart preserves a definite shape and size, varying only with the age and weight of the individual. There occur, however, in

certain pathological conditions well-recognized modifications of shape and size. In chronic Bright's disease the left ventricle becomes greatly enlarged. The nature of this enlargement and change of shape is fairly constant and gives a definite abnormal shape to the pathological heart. Aortic and mitral disease are also responsible for enlargement and change of shape more or less characteristic of these diseases—the heart of aortic regurgitation, for instance, is known as the "cor bovis." Where there is tuberculous adhesive pleurisy or chronic fibrotic phthisis the right side of the heart is often enlarged; and a similar variation is not infrequent with chronic bronchitis and emphysema. Now, with the exception of the latter cases, the cardiac change is associated with an interference with the normal dynamical conditions inside the vascular system itself. On the one hand, the peripheral blood pressure is increased by the vaso-constriction of chronic Bright's disease, or by changes in structure of the smaller vessels in arterio-sclerosis; or, on the other hand, the mechanical efficiency of the pumping apparatus is compromised by the valvular defects in the cardiac apparatus itself, and the enlargement is the result of an attempt to compensate for this defect. When, however, a change in the size and shape of the heart is observed in an otherwise normal vascular system, associated with advanced disease of the lung or chest wall, one has then to deal with the result of extraneous influences—with the effect on the vascular apparatus of forces from without, and the extent to which an interference with normal pulmonary expansion or deficient thoracic movement can be correlated with a change in the size and shape of the heart may be taken as indirect evidence of the part played by the normal respiratory movements as factors which make for an efficient circulation.

The cases in which evidence in support of this contention was present were of two kinds: (1) Cases in which there was present an extensive collapse of the pulmonary tissue; and (2) cases in which there was an advanced degree of rickety deformity of the chest wall. In the great majority of cases of severe rickets collapse is present in addition to deformity.

Cases illustrative of Atelectasis and Cardiac Failure.

CASE I.

A girl of 7½ years, fairly well developed, had a severe diphtheria followed by paralysis of the muscles of deglutition. An aspiration pneumonia was supposed to have followed, and after eight weeks' illness she died. For a fortnight previous to her death she was very pale and suffered from breathlessness, and for some days before death there was oedema of the lower limbs. *Post-mortem* examination showed very extensive atelectasis in both lungs, the right upper lobe and the left lower lobe being completely collapsed; while the remaining lobes were greatly distended. The child weighed 3 st., and the heart weighed 7½ oz. The form of the heart was abnormal. It was broad proportionately at the base of the ventricles and rounded or almost flattened at the apex, and both ventricular walls were hypertrophied. The venous system was engorged, and the parenchymatous organs showed signs of passive venous congestion. The cardiac muscle showed no signs of fatty or fibrotic degeneration.

Fig. 1.—This diagram shows the abnormal shape of the heart, with a broad base and rounded apex.

CASE II.

A boy of 2 years admitted to hospital suffering from bronchopneumonia. He died after an illness prolonged over ten weeks. He was fairly well developed, and the chest was of normal shape. During the last two months of illness he was pale, and his respirations were rarely under 50 per minute, and sometimes were 80 per minute. The pulse ranged between 140 and 160 per minute. While at the beginning of his disease the temperature varied between 101° and 103.6°, for a period of a fortnight during the

last six weeks there was no febrile disturbance beyond an occasional rise of temperature to 101° and 102°. For a few days before death there was oedema of the lower limbs.

Post-mortem examination in this case showed the heart to be enlarged and relatively broad over the whole extent of the ventricles. The interventricular septum, as demarcated by the descending coronary artery, occupied a relatively normal position. The heart weighed 4 oz. and the body weighed 22 lb. On opening the heart, both the ventricles were found to be hypertrophied. Fig. 1 shows the abnormal shape of the heart, and Fig. 2 shows a transverse section of the ventricles with great hypertrophy of the walls, more especially of the right ventricle and the septum. On microscopic examination the cardiac muscle showed no signs of fatty or fibrotic degeneration. The lungs were collapsed along their posterior portions and at places along the anterior margins. Microscopical examination showed that the pathological lesion was one of collapse. While the evidence of old bronchopneumonia was still present, the process was no longer an acute one, and there was no sign of recent inflammation. There was great engorgement of the whole venous system, and passive congestion of the parenchymatous organs.

Fig. 2.—This diagram shows the great thickening of the wall of the septum and of the right ventricle.

Cases illustrative of Chest Deformity and Cardiac Failure.

CASE I.

A girl, 8 years of age, with very extensive rickety deformity of the chest and lower limbs, was admitted to hospital on account of breathlessness. While under observation, extending over five weeks, she had no abnormal rise of temperature. The chest movements were described as being restricted in the upper part of the thorax. The respirations numbered 30 to 50 per minute, and the pulse from 150 to 130 per minute. *Post-mortem* examination showed that the heart weighed 7½ oz., while the body weighed 30 lb. The heart was of firm consistency, relatively broad, and with a somewhat rounded broad apex and short in length from the apex to the base of the ventricles. On opening, it was seen that both ventricles had participated in the hypertrophy, although the most marked hypertrophy was that of the interventricular septum. The right auricle was dilated. The cardiac muscle showed no signs of fibrotic or fatty degeneration. The lungs were greatly distorted in shape. The anterior margins were collapsed, and a line of depression was present on the anterior surfaces corresponding to the site of junction of the ribs with the costal cartilages. The distortion of the lungs at this line of depression was so great as to give the anterior borders the appearance of being tilted forward about 45 degrees from their normal position. The anterior borders were airless, and there was considerable collapse on the posterior aspects of the upper lobes of both lungs. There was no evidence of acute inflammation in the lungs. Examination of the thoracic cavity showed a striking deviation from the normal. It was greatly contracted in its upper half, and this contraction was due to an in-sinking of the ribs along the line of their articulation with the costal cartilages. It was as if pressure had been exercised along this line on either side, in a direction downwards and inwards so as to produce an approximation towards the middle line, and an obliteration of the upper and anterior part of the thoracic cavity. Towards the diaphragm the cavity widened, and the line of depression gradually disappeared. The ribs were firm and well ossified. There was general venous engorgement and passive congestion of the parenchymatous organs.

CASE II.

A boy of 1½ years with extreme rickety deformity of the chest. The chest was of the fiddle-shaped type, very much contracted at the level of the axilla, and expanded at the insertion of the diaphragm. Respirations were rapid and shallow, varying from 50 to 80 per minute, and the pulse-rate was from 150 to 180 per minute. The respiratory movements were confined almost entirely to the abdomen and lower part of the thorax. For a week before death there was oedema of the lower limbs. *Post-mortem* examination of this case showed an abnormal shape and size of the heart. The organ was of firm consistency. It was broad at the base and relatively short from the apex to the base of the ventricles. The apex was rounded off in the arc of a very large circle. The anterior interventricular groove was not displaced relatively. The right auricle was greatly distended. A transverse section through the ventricles showed marked hypertrophy of the walls of both chambers, more especially, perhaps, of the right ventricular wall and the interventricular septum. The shape and degree of the hypertrophy of the heart resembles almost exactly the condition seen in Case II, where there was extensive collapse following a bronchopneumonia, but no deformity of the chest wall. In this case the heart weighed 3½ oz., and the body weight of the child was 21 lb. There was no fatty degeneration or fibrosis of the cardiac musculature. The lungs were distorted, the anterior being marked off by a deep furrow which corresponded in site with the line of junction of ribs with costal cartilages. There was a considerable degree of collapse along the anterior margins in front of the furrows, and there was also extensive atelectasis in the posterior portions of both lungs, more especially in the upper lobes. There was no evidence of recent

inflammation. The thoracic cavity was very much diminished in extent. The only portions which retained their normal contour were the recesses on each side of the vertebral column posteriorly. The anterior mediastinum was almost obliterated by the in-sinking of the ribs along the line of the rosary. The thoracic cavity was enlarged on the plane of the diaphragmatic attachment. The ribs were soft and pliable, and could be bent like green wands. They contained practically no true bone substance. It was possible to cut microscopical sections of some parts of the ribs without subjecting them to a process of decalcification. The venous system was congested, and there was passive congestion of the parenchymatous organs.

On reviewing the results of these observations, one common characteristic emerges—in each case the heart is about double the normal weight relative to the weight of the body, and in each case the enlargement is unassociated with any other abnormality of an anatomical nature in the vascular system. As regards the hypertrophy itself, it is to be noted that while the right side and interventricular septum participate in a greater degree there is also in every case a hypertrophy of the left ventricle. The associated anatomical abnormality is in every case that of a part of the respiratory mechanism—the lungs, the chest wall, or both. The facts, then, which present themselves for correlation are these:

1. General hypertrophy of the heart in an otherwise normal vascular system, with relatively greater increase in size of the right side, ending in cardiac failure.
2. Collapse of the pulmonary tissue and deformity of the chest wall.

The heart of the healthy subject maintains a size which bears a definite relation to the size and weight of the individual, and which is independent of the amount of bodily exertion within very wide limits. The heart of a man who pursues a sedentary occupation is no smaller than that of a man whose occupation involves a moderate amount of physical exertion; and the amount of work performed by the organ may be greatly increased without in any way prejudicing its efficiency or increasing its size relative to the weight of the body. This property of adaptability is inherent in the heart, and is aided by compensatory variations in pressure throughout the vascular system regulated by the vasomotor apparatus. The increase in size of skeletal musculature, resulting from physical exercise, develops *pari passu* with an increase in the weight of the heart; and the extra work entailed on the left ventricle is balanced, as Leonard Hill has pointed out, by the aid afforded by the more active muscles in returning the blood through the venous system; the increased thoracic movements in additional muscular activity contribute also to meet the extra demand which is put upon the circulatory apparatus. Moreover, the cardiac muscle itself would seem to possess the capacity of immediately adapting itself to an emergency; for example, Stolnikow has shown that when a ventricle in diastole is artificially filled so as to contain even six times the normal amount of fluid it is able with the next systole to drive out several times the normal amount; and in the same way an increased arterial resistance is immediately overcome by the succeeding ventricular contraction. The heart thus possesses an enormous power of adaptation, and when it shows signs of great hypertrophy and consequent inefficiency such a condition may be regarded as being due to one or more of the following causes:

1. Increased work, determined either by an increase in the number of beats per minute, as in exophthalmic goitre, or by increased force demanded against abnormal peripheral resistance, as in renal disease or arterio-sclerosis.
2. Some defect in the pumping apparatus itself, such as stenosis of the valvular orifice, or valvular defect causing regurgitation.
3. Failure of accessory powers of circulation, which include the variations in intrathoracic pressure, the expanding and collapsing lungs, and the movements of the skeletal muscles.

When the cases described are viewed in the light of these considerations, it is obvious that the causes referred to under the third heading constitute the main factors in the production of the cardiac enlargement; at the same time it must be recognized that in each case the pulse rate was abnormally high, although even here the increased pulse-rate was probably secondary to the increased respiratory rate or associated with the cyanosis incident to the deficient respiration. In any case, the factors that are anatomically associated with the hypertrophy are: (1) Atelectasis; (2) rachitic softening and distortion of the thoracic wall.

ATELECTASIS AND CARDIAC FAILURE.

In the present state of knowledge it is impossible to determine exactly the modification of physiological respiration which is determined by collapse of a considerable portion of the lung. Possibly a vasomotor reaction plays a part, accommodating the organism to the new conditions, or, as Keith suggests, reflex contractions of the muscular rings of the bronchioles may exercise a regulating influence on the disturbed balance of pressure. The physical changes are those, however, which are most easily estimated. When a portion of lung collapses, there occurs with inspiration distension of the alveoli of the expanding parts; at the same time the relatively diminished pressure in the atelectatic portions determines a flow of blood to these parts, whereas the compensatory emphysema gives rise to a resistance to the blood flow through the distended portions of the lungs. In this way there occurs circulation of a considerable portion of blood through portions of lungs where oxygenation cannot take place, whereas the air circulates through portions where the emphysematous distension of the alveoli hinders the passage of the blood through the capillaries. The results of such a condition are:

1. Deficient oxygenation of blood, with dyspnoea and increased cardiac action.
2. Increased resistance to the flow of blood through the emphysematous portions of the lungs, and the consequent embargo on the right ventricle.
3. Stagnation of blood in the collapsed portions of lung, with the result that the work of the right ventricle is further increased, and in addition the heart is deprived of the assistance of the expanding and collapsing lung in furthering the blood flow.

DISEASE OF THE CHEST WALL IN CARDIAC FAILURE.

The diseases of the chest wall which are here concerned are:

1. Softening of the ribs due to rickets.
2. Deformities due to rickets, tuberculous caries, etc.

It is obvious that where rachitic decalcification has produced softening of the bones, deformity is also certain to supervene. Such processes are most severe between the ages of 9 months and 2 years. As a result of loss of elasticity and subsequent deformity, collapse of the lung tissue is not infrequent, so that the rachitic chest is further embarrassed by the conditions which have been considered in the preceding paragraph.

The nature of rachitic deformity and the extent and distribution of a concomitant atelectasis are worthy of notice because they afford a strong confirmation of the conclusions to which Keith has come regarding the mechanism of respiration in man. In emphasizing the necessity of recognizing surfaces of direct and of indirect expansion on the lung, Keith has rendered a great service to the study of pulmonary diseases in children. He has pointed out that the mammalian lung is not equally distensible in all its parts, and that it does not expand equally in all directions during inspiration. Of the five areas, he says, which one may distinguish on the surface of the human lung, three are in contact with stationary parts of the thoracic wall, and therefore cannot be directly expanded. These three pulmonary surfaces are:

1. The mediastinal in contact with the pericardium and mediastinal structures.
2. The dorsal surface lying between the spinal column and the spinal segments of the ribs—those parts of the ribs to which the erector spinae is attached.
3. The apical surface, the pulmonary area lying in contact with Sibson's fascia at the root of the neck.

These three surfaces, so far as movements of the chest wall are concerned, are relatively stationary. The two surfaces of the lung which are directly expanded are the diaphragmatic and ventro-lateral or sterno-costal; these surfaces are the first to expand on inspiration, and it is only a residue of the expanding force which is left at the disposal of the more stationary surfaces. When one further considers that the lungs of young children are still lobulated and contain a considerable amount of connective tissue between the expanding areas, it will be seen, as I pointed out some years ago, that the expanding force of inspiration is spent to a considerable extent on tissue of little extensibility. There is thus in children an additional claim on the residual expanding force at the disposal of

the stationary surfaces of the lungs after expansion of ventro-lateral and diaphragmatic surfaces.

If these are the conditions in normal respiration, how are they modified if the ribs are soft? It is a well-recognized fact that the rickety deformity manifests itself most in those parts exposed to mechanical strain. The mechanical strain produces a deformity in the first place, and in the second place excites further rachitic softening by its irritation, thus producing for a time a vicious cycle of events. The thoracic distortion is characterized by an in-sinking of the chest wall in the upper part of the ventro-lateral region. Owing to the softening of the ribs, the intrathoracic negative pressure has been able to prevent the expansion of the chest wall over the area of direct expansion. The consequence is that the only area of direct expansion is diaphragmatic, and clinical examinations show that this is really so. In cases of severe rickets the respiratory movements in the upper part of the thorax are scarcely visible, whereas the diaphragmatic contractions are relatively increased, with the result that the abdominal contents are depressed further than in the normal subject.

It must also be obvious that with the depression of the chest wall and the narrowing of the thoracic cavity, the surfaces of indirect expansion become atelectatic. In such cases one finds that the anterior borders of the lungs, as well as the posterior parts lying in the hollow between the vertebral column and the ribs, are collapsed; the centres of the diaphragmatic surfaces of the lower lobes are usually emphysematous, only the narrow margin embedded between the diaphragm and the chest wall being airless.

Thus the pathological variation produced by softening of the ribs bears out Keith's contention as to the mechanism of normal respiration. But in what way does this variation affect the vascular system? The contractions of the diaphragm, which are increased in power and rhythm, exercise such pressure on the abdominal contents as to secure the flow of blood from the venous cistern to the heart. The pressure of collapse of the lung will mean that the negative force, which would otherwise be spent in dilating the infundibuli and alveoli, will be exerted on the vessels, so that the blood can reach the lungs with comparative ease, and it is in the lungs that the serious obstacle presents itself. The pulmonary circulation is secured by three great forces:

1. The driving power of the right ventricle.
2. The suction action of the left auricle.
3. The pumping action of the expanding and collapsing healthy lung.

In the rickety condition under consideration the latter two forces are thrown out of action, so that the whole work of propulsion falls on the right side of the heart.

It cannot be pretended, however, that these considerations of purely mechanical variations by themselves afford a satisfactory explanation of the appearances in the cases detailed above. T. Lewis in his physiological experiments has shown how extremely complicated the relation of respiration to circulation is, and how difficult it is to analyse the factors which come into play under varying circumstances. Mackenzie in his clinical observations shows how in disease the close relationship between cardiac and respiratory rhythm manifests itself; moreover, the fact that both ventricles participate in the hypertrophy in the cases described suggests that part of the strain may be referred to the increased rate of rhythm, and it is not impossible that the increased cardiac rhythm is secondary to the increased respiratory rhythm.

I have recently made two observations which suggest the deeply seated relationship between circulation and respiratory movements. Observing the contraction of the hearts of very young fish with a stereoscopic microscope it was seen that the cardiac beat had a rhythm co-ordinated with the gill movements. In examinations of the lungs of rats and mice it was found that the ordinary striped cardiac muscle is continued on the pulmonary veins as far as the branches of the second and third order. Such muscle is indicative of a direct functional relationship between cardiac contraction and pulmonary function; a relationship which may possibly be maintained in other mammals by nerves. It must be further recognized that the respiratory and circulatory apparatus is dominated by a demand on the part of the

tissues for sufficient oxygen to maintain a normal degree of metabolic activity. Haldane, in view of the extremely high respiratory exchange per unit body weight in the mouse, concluded that the pulse-frequency in that animal must be over 500 per minute. Investigating this point by means of the electrocardiogram Dr. F. Buchanan found that the pulse-rate of the mouse varied between 520 and 780 beats per minute, while the respiratory rate varied between 140 and 160 per minute. The ratio of pulse-rate to respiratory rate is thus about the same in the mouse as in man. Now, Pembrey has found that the respiratory exchange in grams CO_2 per kilogram body weight per hour is 8.4 in the mouse, that is, about fourteen times as great as in man, while the heart-rate is about ten times more rapid than in man. Thus, as Dr. Buchanan points out, while in the mouse the respiratory exchange is fourteen times greater than in man, and the pulse only ten times more rapid, it must be remembered that the relative weight of the heart to the body weight is greater in the mouse than in man; that is, the relatively larger heart of the mouse suffices to maintain a relatively greater respiratory exchange, while the ratio of the pulse-rate to the respiratory rate is the same. Dr. Buchanan and Dr. C. G. Douglas have found that in birds there is the same interrelation between respiratory exchange, relative weight of the heart to body weight and pulse-rate. It is likely, then, that in cases of respiratory embarrassment due to atelectasis and distortion of the thoracic wall a dominating influence on the respiratory and pulse rate is the demand for sufficient oxygen to maintain metabolic activity. This demand is met by increased pulse-rate followed by an increase in the size of the heart. Such a consideration explains why the left ventricle is enlarged to some extent as well as the right.

The problem, however, which these cases present is not speculation as to the nature of complicated processes; it is rather to formulate what may be termed a "correlation of end results," and to answer the question, "Does the circulation suffer from diseased lungs or deficient thoracic movement?" Mackenzie emphasizes the importance of examining thoroughly the posterior aspects of the lungs as a guide to prognosis in cardiac disease. Extremely suggestive in this connexion is his statement that "when the right ventricle is enfeebled, the assistance of the respiratory movements becomes necessary. When the patient lies in bed on one side, the pressure of the mattress on the ribs restrains their movement, so that the flow of blood through this part of the lung is retarded, and oedema results. This can be shown in the early stages, for, when the patient breathes deeply, the whole of the crepitations may soon disappear." A correlation of the evidence in these four cases which have been described leads definitely to the conclusion that the hypertrophied heart, with its broad squat and globular shape, is the manifestation of an effort to compensate for loss of accessory forces of circulation normally present in a healthy expanding lung and thoracic wall. Nor are these cases to be regarded as pathological curiosities. The variations present are only exaggerated examples of a condition which is probably the determining factor in the issue of a large proportion of the fatal cases of so-called bronchopneumonia in underfed children who are brought up in the overcrowded districts of industrial centres. In any case, the observation of over 1,000 cases of measles, whooping-cough, and diphtheria has led me to the conclusion that where an intercurrent bronchopneumonia extends over a period of a fortnight, the progress of the case has, as a rule, been complicated by the occurrence of collapse; in the case of non-recovery the patient has succumbed not to the toxic products of the infecting organism, nor to the noxious products of inflammatory decomposition, but to the severe mechanical strain which has been put on the heart. This strain is due to failure of the accessory pumping assistance of normally expanding lungs, and the almost constant occurrence of varying degrees of cardiac hypertrophy in such cases is very strong evidence in support of that contention. Similarly in acute rickets and in subsequent chest deformity there is great liability to collapse of lung tissue, more especially in the event of the occurrence of an intercurrent bronchitis. Such collapse enhances the disability to which the respiratory mechanism is exposed by the presence of soft rachitic ribs or a distorted and narrow thoracic cavity; the double embargo

thus placed on the heart leads to a hypertrophy which can maintain compensation only over a limited period except under the most favourable conditions. The period of childhood and even of adolescence may in cases of chest deformity be occasionally survived without any considerable degree of inconvenience, and the result of excessive cardiac strain may manifest itself first in adult life. Professor Muir has recently shown me the heart of an adult who had a very marked thoracic distortion, and who died with the signs and symptoms of cardiac failure. In this case there was a greatly hypertrophied heart, which exhibited the broad quadrilateral shape described above. Hence, from the examination of cases of pulmonary disease and of distortion of the thoracic wall, there is considerable evidence for the view that healthy lungs and a healthy chest wall are indispensable for the maintenance of an efficient circulation.

HEPATIC DISTOMIASIS (SHEEP ROT) IN MAN.

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TRENTLER, in 1793, recorded a case in which he found a parasite protruding from a ruptured vein in a man's leg. Although he gave it the name of *Hæmathyridium venarum*, it was in all probability a specimen of *Fasciola (distoma) hepatica*, the liver fluke, and his case the first reported of its occurrence in man. Since that time twenty-three other cases have been described, but some of them are almost certainly not authentic, and have been subjected to very damaging criticism; thirteen or fourteen survive as true examples of what must therefore be regarded as a very rare disease; of these at least four were noted in Great Britain.

Four other species of the *Fasciolidae* are found in man, of which the *Distoma sinense* is the most important, occurring extensively in Japan, China, and India. All these affect the liver primarily. A nearly allied pulmonary parasite (*Distoma westermani*), responsible for a disorder characterized by cough and hæmoptysis, is found in the Far East, cases being sometimes imported into the United States of America. Other forms of distomiasis are due to certain intestinal parasites, and occur mostly in India, while in Egypt especially the *Bilharzia hæmatobia* is responsible for much chronic ill health.

LIFE-CYCLE OF PARASITE.

The *Fasciola hepatica* is found in the gall bladder and bile ducts of sheep. More rarely it is parasitic in cattle, but in them the disease does not run so acute or fatal a course. The eggs of the adult fluke are conveyed by the bile into the intestine, and so eventually reach the water or damp grass which is essential to their further development. After a time, varying from three or four weeks to as many months, according to the time of year, a ciliated embryo emerges from each egg by pushing of the lid. These embryos are known as miracidia, and soon enter a small snail—*Limnaeus minutus*—there to form sporocysts. Although sporocysts may be formed in closely-allied species, no further development takes place. In the *Limnaeus minutus* each sporocyst produces a large number of rediae, and from these again are formed cercariae, which leave the snail and lead an independent existence. When living in water, they appear to the naked eye as small whitish bodies. They may then encyst themselves on the stems of grasses, and in that condition are capable of surviving extremes of heat or cold, and even desiccation.

The cercaria is that stage in the life-cycle at which the fluke becomes parasitic in mammals, and may be ingested while actually in the snail, in drinking water, or on vegetable foodstuffs. It is probable that drinking water chosen at the dictates rather of necessity than desire, and watercress, sorrel, etc., are responsible for the transmission of the parasite to man.

The cercariae, having reached the digestive tract of man, obtain access to the bile ducts, where they attain adult size—about 30 mm.—deriving the necessary nourishment

from the blood of the host, which they imbibe after attaching themselves to the mucous membrane. The ova are then deposited in very large numbers; the fluke dies and becomes encysted, or is excreted.

The discovery of this life cycle dates from the observation that the parasite was never found in sheep whose pastures were contiguous to the sea or to salt marshes. Salt has been found an efficient prophylactic, and is used as such in veterinary practice.

INFECTION IN MAN.

It is obvious that there must be many occasions on which this parasite in the cercaria stage reaches the human alimentary canal, for in many parts of the country much of the drinking water is derived from ponds to which sheep have free access. Yet the disease is rare. This points to the fact that man is by no means an ideal host. It is not unreasonable to suppose that the habit of taking salt with vegetable food has something to do with this, or it may be that his digestive secretions either in their nature or concentration are inimical to the parasite.

The presence of only one or two flukes has been frequently recorded. Murchison's case was that of a man who died after attention in hospital for other reasons. A solitary fluke was found in his liver *post mortem*. On the contrary we find records of more than a thousand parasites in one sheep, and of considerable numbers in man. Perhaps those instances of the finding of only one or two are cases in which a more than usually adaptable fluke has survived in an essentially inimical host; those of the finding of large numbers must, then, be held to signify the loss of resistance on the part of the host towards flukes of no especial virulence.

It is by no means improbable that some instances of this disease have been treated as cirrhosis of the liver or cancer; the means of diagnosis are least available in the remoter country practices where the disorder is most likely to occur.

COURSE OF DISEASE IN MAN.

The *Fasciola hepatica* has been so seldom observed in man that it is not easy to judge of the symptomatology from the recorded cases. A consideration of the disease as it affects sheep, and of the effects of the allied parasite *Distoma sinense* will, however, allow one to arrive at a fair idea of the disease process.

The period of invasion may pass unnoticed clinically, and in the early part the host may gain weight and enjoy a good appetite. There may, however, be slight jaundice and moderate enlargement of the liver. In sheep the minimum duration of this stage is six weeks; in man it is probably longer. Secondly, the stage of anaemia is recognized, and this is supposed to coincide with the maturity of the flukes. Anaemia of the mucous membranes is the most obvious sign, but the symptoms are rather those of toxæmia; in the case about to be considered they were certainly quite disproportionate to the anaemia. Appetite fails or may become depraved, the temperature is irregularly elevated, and the frequency of the pulse increased. Gastric pain and intestinal disorders become evident, diarrhoea and vomiting are not unusual, constipation may be present. The eyes are lustreless and the skin dry; experienced veterinary surgeons have been known to base a diagnosis on the condition of the skin alone.

Slight exertion aggravates the dyspnoea which is present, and the third stage soon appears. This is the stage of emaciation and ascites, and is accompanied by increased anaemia and progressive hepatic derangement. Oedema of the eyelids, conjunctivitis, hydrothorax, bronchitis, ascites, and jaundice are among the common symptoms.

The fourth stage seems to correspond in time with the emigration or excretion of the parasites, and in those who have survived the third is one of slow recovery from toxic symptoms. Fibrosis and other changes in the liver remain, and may cause permanent ill health.

An infinite variety of catastrophes may ensue from the presence of flukes in parts of the body other than the liver. These migrations are by no means uncommon; 10 per cent. of all cattle affected are found to have flukes in the lungs, and in the human being they have been seen even in the eye. One case was that of a child, 2 months old, who had an abscess of the scalp, which contained liver flukes; in another they were found in the sole of the