A British Medical Association Lecture

ON

THE PRESERVATION OF A HEALTHY AND EFFICIENT CIRCULATORY SYSTEM FROM CHILDHOOD TO ADVANCED AGE.*

BY

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THERE is one point which I wish to emphasize at the outset: you cannot have a clear and comprehensive knowledge of diseases of the respiratory and circulatory systems without a good conception of physics. Time will not permit me to deal with these matters here except on broad lines, but there are several of my papers where you will find the physics in full detail.

I am more concerned with the preservation and efficiency of health than the mere prolongation of life: a sound mind in a sound body—the former can scarcely exist without the latter. When I travel outside the beaten paths of traditional medicine I do not wish you to accept anything which I say until you have proved it for yourselves. The only knowledge worth anything is that which you acquire for yourselves and make your own. Prove all things, hold fast to that which is good. Accept facts and not mere opinions, no matter by whom uttered.

The objects of the circulation are to convey oxygen and nutritive material to the tissues, and remove carbonic acid and other waste products therefrom. I look upon the circulatory system as one unit, but although we have numerous books on diseases of the heart, it is only of recent years that much attention has been paid to the distributing tubes. When in 1906 I gave the address at the meeting of the British Medical Association in Toronto on the circulation viewed from the periphery¹ it was generally considered that I had opened up a new vista. On many occasions I have dealt with the parts played by the arteries, arterioles, capillaries, and veins.²

The old trite saying of Cazalis, that a man is as old as his arteries, should be extended—that his arteries are as old and efficient or inefficient as his endocrine glands. The part which these organs play in the maintenance of an efficient circulation is not yet fully recognized. The preventive side of medicine, apart from that dealing with infectious diseases, which I believe is going to be the medicine of the future, is only slowly developing. The reason for this is that prevention does not pay the individual practitioner, and the public do not believe in paying for what may never happen. Moreover, it is not always an economic proposition; when a public health officer tells me that in his particular city he has saved so many thousands lives, and actually has the temerity to put a money value on his work, I retort that I would like him to trot them out, and let me see whether they were worth saving, and how long the saving process is likely to last. I believe that every person dying under the age of 20 is an economic failure. Nature weeds out the unfit, and enormous sums of money are spent yearly in thwarting Nature, but in the long run progress must be established and Nature gets her way. R. J. Ewart recorded in the *Eugenics Review* how a few wet summers had enormously reduced the death rate from infantile diarrhoea, but an epidemic of measles came along and wiped out all the inefficient lives that had been saved. War is dysgenic, and in the late great war millions of the fittest of the fit were killed. While our A 1 men were sacrificing life and limb the weaklings at home were propagating the race, but Nature was not going to be thwarted all the time; she came along with a world-wide epidemic of influenza and wiped out more of the weaklings than the numbers of the fit killed in the war. If you want an A 1 race you must breed it; there is no other way. You must apply genetics to the human race just as you do to the lower creation. We want children of choice, not of chance, which is the

usual haphazard method in the present day. Those who cannot produce healthy children should leave the job to those who can.

There is no part of the animal economy more under hereditary influences than the circulatory system. We get our health, physique, intellectual capacity, and longevity, in fact, the harmonious working of our endocrine system, from our progenitors. I know that there are many of our profession so imbued with Lamarckian ideas that they will tell us that all children are born healthy, that their potentiality for life is equal, that their bad health depends on the environment. Such doctrines are scarcely worth refuting, as there is no such thing as equality in Nature, not even in the same family. The Mendelian laws should be widely studied and carried out. We should take lessons from horticulturists and animal breeders. The nation that produces the finest and best race is sure to win in the long run. Of course, we do not wish to raise a race of hot-house plants; every progressive race must take risks—the safety first principle never made any nation.

When we get children with healthy circulatory systems it will be necessary that we should know how to keep them not merely healthy but efficient to advanced age. Of course, the circulation of a clerk might be as healthy as that of a navvy, but it would not be as efficient, though it might wear longer. It is unfortunate that we measure the length of our existence by the number of revolutions we have had round the sun rather than by the work which we have accomplished. Before Einstein appeared on the scene it might have been argued, and was successfully argued by many ancient philosophers, that there is no such thing as time; certainly so far as our senses are concerned it is a physical nonentity. A revolution of the earth on its axis we arbitrarily divide into twenty-four parts, which we call hours, and if we are at the Equator we are being whirled round at the rate of 1,000 miles an hour without knowing it. Our orbit round the sun we divide into 365½ days, and during this excursion we travel at least 68,000 miles an hour. The question, in my opinion, is not how many of these excursions we have had, but what have we been doing? If we be merely parasites the fewer revolutions the better for the nation. What troubles me is that many of our best and most worthy citizens after they have had sixty excursions suffer from a failing circulatory apparatus and die in the most useful period of their lives. They must be taught how to lessen this wasteful mortality, and preserve their utility to a more advanced age.

Many medical men talk very glibly of inductive philosophy, without any clear apprehension of what they mean except that they patronizingly mention Bacon as their guiding star. Bacon, in his description of his method of physical inquiry, lays down the principle by which it is to be guided, but, as Edward Caird pointed out, he exhibits no idea of connecting that method, or those principles, with self-consciousness. He usually speaks as if facts were given through the senses without any aid from reason. When physicians and surgeons speak of their experiences and trot out their thousand cases they fail to see that the mere accumulation of statistics without a guiding principle is useless; a single negative may upset a year's work. Unfortunately, the negatives are too often slipped into another category, or buried, and you hear no more about them. If we are to arrive at any sound conclusion, either by deduction or induction, the critical faculty of reason must be employed; even of our own existence we must be self-conscious. As Descartes said, *Cogito, ergo sum*.

Einstein now seems inclined to join up the electro-magnetic and gravitation fields. I think in medicine we should pay a little more attention to the electro-magnetic field than we do. Supposing one stands on the crown of his head, he might not materially alter his position in the magnetic field, but he certainly would in the gravitation field. This is not a practice which I recommend except for experimental purposes. Some young men with good healthy pliant blood vessels can do so with impunity, without any risk of injuring a single cerebral capillary. We must not think that thin-walled capillaries are subjected to the brunt of the ordinary blood pressure with the addition of the weight of a column of blood five or six feet in height. Once the body is inverted the carotid

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arteries contract to a half or less of their former dimensions. Then not only is the blood supply diminished, but the increased lateral pressure in the arteries enormously increases the velocity in the arterioles, capillaries, and veins. In these small vessels the velocity and lateral pressure stand in an inverse ratio to one another, so the lateral pressure in the capillaries may be actually diminished. The question of pressure and velocity in all the capillaries of the body was fully discussed in my Toronto address.¹ In my experiments I was the first to discover that the venous blood runs more quickly up the hill than it does down it. This is a claim which no one has ever disputed. The fact is explained when it is recognized that the velocity in the veins depends on the pressure in the arteries.

The principal cause of disease of the heart in early life is acute rheumatism, and therefore if we could get rid of rheumatic fever we would materially lessen the incidence of heart disease. With this object in view an influential committee was appointed by the British Medical Association. It has been at work about three years, and has discovered that 60 per cent. of cases of juvenile rheumatism occur in damp houses; they therefore jump to the conclusion that damp houses are the cause of rheumatism. Architects have been called in, so the prevention of rheumatism is going to be a very expensive business, like most health work undertaken by clinicians. There is nothing said about the 40 per cent. who presumably live in dry houses; otherwise, on any pretext, they would have been used to swell the 60 per cent. There is no mention of the little street urchin who is badly housed, badly shod, badly clothed, badly fed, and exposed to all kinds of weather, but is not particularly prone to rheumatic fever. Too many of our specialists pay no attention to Newton's dictum, if they ever knew it, that we are to admit no more causes of natural phenomena than such as are both true and sufficient to explain their appearance.

Very many years have elapsed since I pointed out that large numbers of children under the age of puberty suffer from defective action of the thyroid gland. Consequently, in Nature's imperfect attempt to remedy the defect, we get increased growth of the lymphoid tissue, adenoids, large tonsils, and subsequent infectious diseases such as rheumatic fever. In these cases there is a defective supply of iodine with lessened calcium metabolism, and an accumulation of lime salts in the tissues. I recommend that a large lump of iodine (or its tincture) be placed in the dormitory in an open vessel near the window, so that the air entering the room may take up a fair amount. The benefit derived at many seaside resorts is partly due to the iodine in the atmosphere. In many cases this is not sufficient, and the medical attendant should exercise his educated judgement as to the amount of iodine and thyroid that should be prescribed in individual cases to prevent the onset of these diseases. Iodine is the natural stimulant to the thyroid gland, and as a rule it is best to make the thyroid do its own work, though in some cases the addition of thyroid may be necessary. The amount necessary for prevention is usually not great, and we must be careful not to overstep the mark, as I have known exophthalmic goitre to be produced by excessive doses of iodine.

Rheumatic fever is supposed to be due to some streptococcus introduced chiefly by the tonsils. Throat specialists have intervened and say the tonsils must be enucleated, so "the latest thing out" is the tonsils. The tonsils often act as a barrier to the entrance of septic organisms to the chest. The enucleation not only removes the filter-bed to the entrance by the lymphatics, but blood vessels are opened up so that infection can get directly into the circulation.

Acute rheumatism occurs more frequently in the children of the artisan class than among the very poor; among these who have had a liberal supply of milk, and have an excessive amount of lime in their fibrous tissues. In rheumatic fever milk should be cut out of the diet, and there should be substituted meat juices, soup, raisin tea or glucose, potassium and sodium salts, and, of course, salicylates. In order to prevent the heart becoming involved the blood pressure should be kept very low. It is always possible to tell when the heart is becoming infected, several days before

there is any murmur, by a long dull first sound, and a perceptible delay in the transmission of the pulse wave to the wrist. In addition to the myocardium, the chief valves to become involved are the mitral and aortic. The lesion in the mitral valve² arises in the auricular surface about a quarter of an inch from the edge where the cusps come into violent collision, and in the aortic valves in the ventricular surface, where the cusps are driven into forcible apposition by the recoil of the aorta.

Pericarditis is also of frequent occurrence, and when there is excess of lime we get a thick honeycomb effusion which may eventually be absorbed, but when the effusion is more gelatinous and corpuscular adhesions readily take place. The way to prevent the mischief is to keep the blood pressure low, lessen the lime supply, give salicylates with a liberal supply of sodium and potassium citrates or bicarbonates, iodine or the iodides. When the acute stage is over mild exercise is desirable. Absolute rest is the modern treatment, but fortunately it is impossible to make a child a fixture. Avoid heart tonics such as digitalis—irreparable mischief is often caused thereby.

In the *Edinburgh Medical Journal*, December, 1876, I wrote an article on the effects of overwork on the heart and aorta. At that time the British workmen worked, nowadays they play, so that any stress on the heart is usually brought on in the playfields; but as any strain thus incurred is intermittent its effects soon pass away. We hear a good deal about "industrial fatigue," and some men seem to be making a living out of it, but I have not come across anything of the kind for at least a quarter of a century. If excessive strain be too frequently produced, no matter how caused, it tends to dilatation and hypertrophy of the heart, with damage to the aorta and other systemic arteries.

German beer-drinkers used to work hard and drink hard. The low alcoholic strength was sufficient to keep up a constant vasomotor paresis, and thus increase the blood vascular cavity, which was always replete; the quantities thrown out at each beat were large, the systemic blood pressure was always high, with a great disparity between it and the diastolic, so that in addition to the lateral there was also longitudinal strain in the aorta and other large arteries. This led to proliferation of the star-shaped corpuscles in the subendothelial layer of the intima of the large elastic arteries, with subsequent fatty and atheromatous degeneration. In the muscular arteries the degeneration takes place in the media. This leads to loss of elasticity, which occurs most readily when the vessels are constantly on the stretch. The free calcium ions in the blood are deposited in the atheromatous patches as calcium soaps, and afterwards the fatty acids are replaced by phosphoric and carbonic acids. We thus get calcareous plates, which may strengthen the affected parts, but still further reduce the elasticity.

The blood pressure in the arteries is merely a part, though a very important part, of the energy imparted to the blood by the contraction of the ventricles. The energy of the blood in any part of the circuit is a compound of potential and kinetic energy, of lateral pressure and velocity, and the greater the velocity in any part the less the lateral pressure in that particular part. The same considerations apply to the pulmonic circuit, except that the energy is, as a rule, not more than a third of that of the systemic system. There is an important difference as to how the energy of the right ventricle is expressed in comparison with the left. I have calculated that while the pressure in the pulmonic artery is not a third, the velocity is at least three-fourths of that in the aorta. Unlike the vena cava, the pressure in the pulmonic veins is practically always positive, so that the blood enters the left side of the heart under pressure, while it is usually sucked in, or rather driven in, by the atmospheric pressure to the right side. There is a gradual fall in the pressure gradient from the right ventricle to the left auricle, and, as the vasomotor nerve supply to the pulmonary vessels is very limited, there does not seem to be much resistance to the circulation either in the arterioles or capillaries. The blood pressure is considerably raised in the pulmonic circuit in cases of mitral stenosis, and it is in this disease that degenerative changes chiefly take place, and are as

pronounced in the pulmonic veins as in the pulmonic arteries.

A certain degree of blood pressure is essential to the maintenance of life, but the variation has a very wide range to meet the ever-varying demands of the system. What is normal blood pressure either for the individual or the species has never been, and never can be, determined, because the pressure must vary according to the calls of the organs for more or less oxygenated blood. Without a certain diastolic pressure man could not assume and maintain the erect posture.

The primary cause of arterial blood pressure, high or low, depends on the force of the ventricular contractions and the amount of blood thrown into the circulation at each stroke—two variables within fairly wide limits. According to some physiologists the limits of the output are very wide—say, two to fourteen gallons of blood passing through the two ventricles in a minute. This would be all very well for a bullock, but not for human beings. I would advise the output be kept well below this physiological maximum. The greatest toper could not pass nine gallons of beer into his stomach in a day, and, after absorption, that would keep the pump very active, but, I think, scarcely up to fourteen gallons a minute. The pressure also depends on the height of the blood column; hence, in the erect posture, the pressure on the tibial artery is much greater than in the radial raised above the head. It is therefore customary and advisable to take the arterial pressure at the level of the heart. In the healthy adult who is not subjected to much physical stress the systolic arterial pressure may range, say, from 100 to 150 mm. of mercury, while below 100 might be put down as sub-normal, and over 150 as supernormal or hyperpiesis. While the heart starts the circulation the maintenance of the pressure largely depends on the resistance to the outflow through the arterioles and the capillaries. A healthy heart has a wonderfully adaptive capacity, so that its reserve force can be called upon at any time to do five or six times as much work as is required of it in ordinary quiet life. It is a self-regulating and self-repairing force pump, so that if there were less tinkering with it the gear would last much longer.

The greater the resistance or amount of work to be done the greater the force of the cardiac contraction, and the higher the lateral pressure within the arteries. If the load be too great the heart may not be able to cope with the work, and we get cardiac failure with subsequent abatement of the resistance, so that the heart again may be able to adapt itself to the lessened work. A long-continued high pressure leads to hypertrophy of the heart with increase in the thickness of its walls, and perhaps in the capacity of its cavities, especially when there is a demand for an increased supply of blood; these conditions in turn maintain the arterial pressure at a high level.

As the blood leaves the heart its energy is largely kinetic, and therefore during the systolic period there must be very little lateral pressure at the root of the aorta; but if that vessel be healthy and elastic the largest portion of this energy is rapidly stored up in the walls as potential, which is paid out during the diastole of the heart, and then the blood is compressed with a force nearly equal to that which it transmitted, and this force is equally applied to all parts of the aorta, including its commencement. Thus the blood is driven through the coronary arteries when they are relaxed.

At the opening of the semilunar valves the blood has acquired its velocity head, and then the actual velocity depends on the energy or effective head *minus* the resistance to the outflow. In a large smooth-walled vessel the friction and viscosity of the blood are negligible quantities, but both come into play in the arterioles and capillaries; and the mass of blood is an impediment to its onward movement.

The greater the elasticity of the aorta, the greater the conservation of energy, and hence the pressure and the velocity become more or less uniform during the whole diastolic period. The velocity between any two points depends not on the pressure, but on the difference in the pressures—the pressure gradient. The most perfect circulation is the one with a relatively small difference between

the systolic and diastolic pressures, a moderately low systolic and a relatively high diastolic pressure in all the arteries. The systole of the ventricles gives out the energy during the third of a cardiac cycle, and the perfection of the circulation depends on the disposal of that energy not only in the time it is given out, but also in the intervals between the systoles. The diastolic pressure should be more than sufficient to overcome all the resistance, otherwise the blood in the main arteries would come to a standstill towards the end of the diastole. We can therefore look upon the difference between the systolic and diastolic pressures as that part of the energy which is not stored up in the walls of the arteries, and which is used in producing velocity. I think when this difference ordinarily exceeds 40 mm. of mercury there is something wrong with the elasticity of the aorta. This difference between the systolic and diastolic or mean pressure is nowadays called the pulse pressure. I know that the majority of heart specialists look upon a high pulse pressure as evidence of a very efficient circulation, but I think that such an opinion evinces gross ignorance of the physics of the circulation.

A pressure gradient of 5 mm. of mercury in a smooth-walled vein without any resistance gives a velocity of 1,120 mm. of blood in a second, but in an artery, in order to get this velocity, a fall in the pressure gradient from 150 to 100 mm. of mercury is required. With a pressure of 150 mm. and a resistance of 120 mm. of mercury you get a velocity of 640 mm. in the second. This is the kind of circulation that would suit a Methuselah, but it is not often realized.

The estimation of arterial blood pressure with one of the numerous instruments on the market is a very simple matter; hence such instruments are in very common use, and many patients think they have not been properly examined unless their blood pressure has been taken, while, if they are able to display an electro-cardiogram they think their money has been well spent. Such random observations are of very little value; it is not the instrument, but the man behind the instrument, that makes or mars the observation.

We must now consider how the arterial pressure is increased, maintained, and regulated by the resistance to the outflow. The first line of resistance is in the arterioles, which are small muscular vessels well supplied with vasomotor nerves, and consequently readily contract on any stimulus; the resistance in the arterioles is directly as their length and inversely as the square of their cross-sections, or the fourth power of their diameter. Here friction and viscosity come into play, but not to the same extent as in the capillaries. The arterioles of the splanchnic area, of the skin, and to a less extent of the muscles, are the great regulators of arterial pressure. Often their action is reciprocal; when one set is contracted the others are dilated. The arterioles of the muscles dilate after exercise; hence after a strenuous sprint one may have violent palpitation owing to the great fall in the pressure gradient.

The principal secretory organs which stimulate the vasomotor nerves are the adrenals and the pituitary. The thyroid, through the sympathetic, stimulates the heart's action, but it lessens the viscosity and the resistance. Both the adrenals and the pituitary, besides their specific effects, raise the blood pressure and lower carbohydrate tolerance. There are numerous pressor agents which act through the vagus or sympathetic nerves, such as digitalis, squills, caffeine, strychnine, and many toxins. On the other hand, practically all the bacterial diseases lower the pressure. Hard mental work, and the stimulating effect of cold acting through the sympathetic, contract the arterioles, raise the arterial blood pressure, and increase the urinary flow.

The contraction of the arterioles of large tracts raises the general arterial blood pressure, but when those of small areas only are affected merely local effects ensue. Take a cold hand: there may be a difference of 50 mm. of mercury between the lateral pressure in the radial and in a digital artery, but when the arterioles are dilated there is a much less abrupt fall in the pressure gradient. Frequent contractions and dilatations of these vessels are

sufficient to give rise to tortuous and atheromatous radials, while the central arteries may be quite healthy. It is entirely due to the intervention of the arterioles that the capillaries are protected from the full hydrostatic effects of the blood when the body is in the erect posture.

When the limbs are dependent the potential increases, and if the arterioles be dilated from any cause the pressure in these little vessels and in the capillaries is much augmented, so that petechial haemorrhages may readily occur; but, on the other hand, if the arterioles be contracted the potential is largely converted into kinetic energy in the arterioles and capillaries.

The marvellous regulative mechanism of the vasomotor system enables the blood to be drawn from the high-pressure main—the aorta and its principle branches—to the organs or systems that immediately require it. Witness the great supply to the extremities during exercise, and to the abdominal viscera during digestion. Increase of pressure within a healthy artery improves its tone and raises its coefficient of elasticity. Owing to these facts, as well as to the intervention of the vasomotor nerves, the arteries of the lower extremities contract when they are dependent and dilate when they are raised.

The second line of resistance is in the capillaries, and here it is a compound of potential, friction, and viscosity. The larger the capillary bed the less the resistance. Perhaps not more than a third of the capillaries of the body are full at any time, but when there is great vascularity owing to dilated arterioles the inertia of the mass of blood is an impediment to its onward motion, and in the web of the frog's foot a to-and-fro movement can be seen. In these little tubes there is an enormous amount of friction of the corpuscles against one another and the walls. The resistance is, as in the arterioles, directly as the length of the tubes, etc., and here the viscosity is an important element. The extra-capillary pressure is about one-fourth of the capillary pressure from which it is derived, and is a factor in carrying on the lymph circulation.

Calcium Salts.

Lime salts play a very important role in the animal economy. Without free calcium ions life as we know it would be scarcely possible in the animal and vegetable worlds. Fortunately calcium is very widely distributed over the face of the globe, but mostly as dead inert matter, which, however, can be readily converted into soluble active forms. When I began my work with calcium in the early eighties practically the only soluble salt was the chloride, and most of my experiments were carried on with it. I think very highly of it still, though chemists have placed many more palatable forms on the market.

When, in 1910, I gave my address on the use and abuse of lime salts in health and disease,⁴ I naturally referred in very eulogistic terms to Sydney Ringer's epoch-making work. To appreciate Ringer's work properly one should read it carefully, and then, by way of contrast, peruse a discussion at the Edinburgh meeting of the British Medical Association on the therapeutic uses of the calcium salts.⁵ If you have the patience to wade through this discussion, then by way of a tonic I would commend to your attention a discussion at the Liverpool meeting in 1912, "On the role of the calcium salts as therapeutic agents."⁶

The lime salts are as a rule badly absorbed, and it is not what is taken into the stomach, but what is absorbed, that works good or evil. Benjamin Moore was the first to point out that calcium is absorbed by the intestinal mucosa as a calcium soap, and when it passes in by the lacteals the calcium ions are set free to play their important role in the animal economy. The stearin and palmitin form insoluble calcium soaps, which pass out by the rectum. We are now told that vitamin D increases the absorption, but we are not told the composition of vitamin D; nor what chemical combination it forms with lime. It is easy to know all that is known about vitamins, and if one acknowledges that he does not know what is not known, his patients may think him very ignorant and much behind the times. Vitamins can be bought by the ton at a very substantial price, yet no chemist, nor even a biochemist, has been able to discover their chemical composition; the nearest

approach is that when some of the sterol compounds, such as ergosterol, are exposed to the mercury vapour lamp they become charged with vitamin D, and you must be careful not to overcharge lest the stuff become poisonous. It may thus turn out that vitamins are vibrations in the ether of definite wave-lengths, and a biophysicist may eventually be able to measure the wave-length and determine the dosage.

One of the earliest signs of pneumonia is the disappearance of lime from the urine; it is discharged from the blood with the fibrinous exudate into the alveoli. It is a bad omen when there is a deficiency of calcium in the blood with prune-juice expectoration. All these examinations are within "the competency of any ordinary general practitioner," and should be made within twenty-four hours of the onset of the attack. One should not wait six weeks and get a biochemist to make the discovery.

When in 1907 Blair Bell introduced his method of examining the blood for calcium, many of us examined the blood in all kinds of diseases for the lime salts. I quickly came to the conclusion that his method revealed the free calcium ions and not the fixed lime. In one gentleman aged 74 there was a large amount of fixed lime in his arteries, yet by Blair Bell's method his blood only gave an index of 0.5, or half the normal amount. I put him on a lime-free diet and gave him decalcifying agents freely, such as lemon squash and phosphoric acid. In a short time the calcium index had risen to 1.3. Blair Bell has now come to the same conclusion. I found that the lime salts increase the viscosity of the blood and lessen the velocity of the capillary circulation.

My conclusions are that the fixed lime, or that which is linked on to the molecules of albumin, increases the viscosity, while the free calcium ions in association with the suprarenal and pituitary secretions increase the tone and contraction of the arteries and arterioles, raise the blood pressure, and improve the force and efficiency of the cardiac contraction. In this latter effect the ions of potassium and sodium play an important part. The viscosity is augmented by an increase in the number of corpuscles, by cold, and by carbonic acid. The adrenaline and probably pituitary secretions lead to the retention of lime salts in the blood and tissues, while the thyroid and ovaries increase calcium metabolism, diminish the free and fixed lime in the blood, and thus lessen the viscosity; the parathyroids also increase calcium metabolism, but this is anabolic, while the action of the thyroid and ovaries is katabolic. Although we cannot show with the sphygmometer that a dose of calcium—except intravenously—materially raises the blood pressure, we have the direct evidence that decalcifying agents quickly lessen the viscosity and pressure. These agents do not always lessen the free calcium because they take up a good deal of the loosely fixed lime in the blood vessels and other tissues. Under the free use of phosphoric acid I have seen the free calcium ions increase, while coarse valvular murmurs abated and in some cases disappeared. The blood is the agent for conveying the calcium to the tissues, and from them, when it has served its purpose, to the excretory organs. The lime salts are very apt to get deposited in any part of the body which is not properly functioning. I have seen calcification in the costal cartilages of a man aged 27, produced under the care of an orthopaedic surgeon by long fixation of the chest with a spinal support. Emphysema leads to calcification of the costal cartilages, and, on the other hand, a fixed rigid chest may be the precursor of emphysema, hence the great value of mountain climbing in maintaining a good vital capacity.

Arterio-sclerosis.

However high blood pressure is brought about, it eventually leads to degenerative changes in the coats of the vessels. As the degenerative changes proceed the arteries—especially the aorta—lose their elasticity, consequently the energy imparted by the heart to the blood is not properly stored up, there is a great fall in the pressure gradient between the systolic and diastolic pressures, which leads to longitudinal straining of the arteries, the arch of the aorta gets dilated, and the muscular arteries become tortuous. The best way to prevent and lessen these degenerative changes is to maintain a low systolic and a

relatively high diastolic pressure. We may not be able to regulate the secretions of the adrenals and pituitary, but we certainly can control the high pressure effects which they produce. We can stimulate the thyroid with iodine, also supply thyroid substance, and so increase calcium metabolism.

If the degenerative changes in the aorta have not proceeded too far—and this is most readily measured by the difference between the systolic and diastolic pressures—it is really wonderful what the free and long-continued use of decalcifying agents can accomplish. I have seen aortas which were so much dilated that they could be easily felt in the suprasternal notch, and the elasticity greatly impaired, as indicated by the loud, clear, clanging second sound, diminish in size and the second sound become quite normal. I have seen coarse, rough valvular murmurs and cardiac intermissions permanently disappear. Healthy exercise increases calcium metabolism and lowers blood pressure, and for good health a considerable amount of exercise is absolutely essential.

Women are not so liable to arterio-sclerosis as men because their foot-ton output is not so great; they eat less, are more temperate in all things, and, as Blair Bell has shown, they get rid of a good deal of calcium at each menstrual period. When it does occur in women, apart from kidney disease, it chiefly arises in those who have borne large families and in those liable to emotional disturbances; emotion acts like suddenly turning a stopcock in a water-pipe connected with the main; it sets up waves of pressure, the chief stress of which is thrown on the aorta.

In Stokes-Adams disease⁷ the contraction of the left ventricle, although very infrequent, is powerful and fairly regular; the systolic arterial blood pressure is high and the diastolic low; there may be two or three ineffective contractions of the right ventricle between the powerful systoles of the left. In these cases you should try to increase the irritability of the cardiac muscle, lessen the remainder contraction of the ventricles, hasten ventricular diastole, and increase intracardiac pressure. To lessen the remainder contraction and hasten diastole active potassium ions are necessary, while the sodium salts should be diminished. For the maintenance of efficient cardiac contraction free calcium ions are essential. Since all agents which increase calcium metabolism do good I have found a useful combination of calcium iodide, potassium chloride, and tincture of iodine, supplemented with thyroid. There is plenty of fixed lime in the system, so what is wanted is not an additional supply but some agent to set the ions free.

I do not pay much attention to the imaginary function of the sino-auricular node as the pace-maker, nor to the stimulus which it is said to generate. This stimulus, if such exists, must be a vitamin, since it has never been isolated nor its composition determined. In very many people after the age of 50 the function of the thyroid begins to wane and the pulse becomes infrequent. I think most people with a slow infrequent pulse will find a great advantage from cutting down the lime salts, and taking a small daily dose of iodine and thyroid.

If we find a person in a dead faint we should not wait for the pace-maker to start the heart, but raise his lower extremities so as to increase the intracardiac pressure in the right auricle and ventricle. This is the best cardiac stimulant, and as the right side of the heart is more irritable than the left, it starts contraction, raises the intrapulmonary pressure which drives the blood into the left auricle. The rhythmic cardiac contraction depends on the difference in electrical potential between the ions within and without the muscle cells; more attention, therefore, should be paid to electrolytes than to an imaginary stimulus which has never been traced outside the brains of cardiologists.

As a matter of routine, in my examinations of the urine I always precipitate the lime as an oxalate. This helps me to estimate not only the activity of the kidneys but also the calcium content of the blood. In all these examinations the condition of the kidneys and the specific gravity of the urine must be taken into account.

In 1908 I was waiting in one of the operation theatres of the Liverpool Royal Infirmary to see an operation on a patient of mine. I heard a noise in the anaesthetic room, passed in, and

found the anaesthetist and a nurse busily engaged in performing artificial respiration. I was informed that the patient had ceased breathing. I said that judging from his pulse and colour there could not be much the matter; that if they stopped the artificial respiration and threw a towel over the patient's mouth so as to allow CO₂ to accumulate in the alveoli he would soon start breathing. The anaesthetist mentioned that he had seen this occur in several cases when the ether had been administered by the open method.

When apnoea is established from excess of oxygen and deficient carbonic acid—which is the natural stimulant to the respiratory centre—the worst method of treatment is arterial respiration. We often see reports of inquests where artificial respiration was carried on for hours. The medical attendants get great praise for their perseverance, whereas it would be more correct to say that they deprived the patient of any chance of recovery. It is doubtful if anyone could stand two hours of artificial respiration and survive. In many diseases the free administration of oxygen establishes a partial apnoea, but we must not think that because the patient appears more comfortable we have increased his chances of recovery; on the contrary, we have deprived the heart of the assistance of the respiratory pump. The old closed ether inhaler might half-suffocate the patient, but it never induced a fatal apnoea.

Before prescribing a cylinder of oxygen one should carefully weigh the pros and cons. If one feels *certain* that it is going to do any good, then let him prescribe it, but it should not be ordered because it is the popular thing to do, or merely on the erroneous idea that it can do no harm. There is much more oxygen in the atmosphere than the blood can under any circumstances appropriate, but the atmosphere ought to be pure and fresh, not pre-breathed. An excellent respiratory stimulant is to play with a fan a stream of cold air on the patient's face. Before we had electric fans I used a foot-bellows.

Auricular Fibrillation.

This is a very common precursor of death, and when the fibrillation extends to the ventricles life can be measured by seconds.

There was a very interesting case of hemisystole in a woman, aged 41, admitted under my care to the Liverpool Royal Infirmary on August 6th, 1908, and she died suddenly on October 4th.⁸ I made very full notes of her case, with cardiographic tracings, which were verified at the necropsy. I did not see her for the last ten days of her life, as I was on holiday. She must have had several attacks of auricular fibrillation, which was not then usually recognized as a clinical entity, though many years previously Professor MacWilliam had experimentally produced it in animals. At that time we were examining the blood of most patients for calcium. Her blood was examined several times by my clinical assistant and the house-physician, Dr. Pantland Hick and Dr. Gerrard. On only one occasion were the free calcium ions found to be normal. The following is abstracted from the notes of the post-mortem examination made by Professor E. E. Glynn: "Heart 14½ ounces; auricles normal. Right ventricle slightly hypertrophied and dilated; valves normal. Left ventricle hypertrophied and cavity smaller than right; muscular papillares thick; mitral orifice admits two fingers; mitral cusps thickened, and a hard calcareous nodule about the size of a pea in the posterior cusp. Aortic valves normal. A section of the heart muscle stained with osmic acid showed no evidence of fatty degeneration." I said that I could see no reason why this heart should have stopped in diastole unless there was a deficiency of calcium. Accordingly Pantland Hick took 5 grams of the muscle of the right and left ventricles respectively, and macerated each in 5 c.cm. of decinormal hydrochloric acid. He then examined for calcium according to Blair Bell's method, and found that the muscle from the right ventricle gave an index of 0.3, and that from the left 0.7. By this process the whole of the lime, fixed and free, was extracted, so the amount of free calcium in the muscle was very scanty. This was a lesson for me from which I hope I profited.

I was the first to discover that by eliciting Abrams's cardiac reflex of contraction I could arrest an attack of auricular fibrillation in five minutes, but this is not a cure; the reflex must be frequently repeated to prevent overloading of the right auricle and recurrent fibrillation, until the heart is well charged with calcium. To prevent repeated attacks digitalis, strophanthus, and pilocarpine can be used. The old Guy's pill to which has been added one grain of quinine sulphate answers admirably. This pill should only be continued for a short period. A tonic of

pilocarpine, strychnine, quinine, phosphoric acid, and syrup of the glycerophosphate of calcium is useful at any time. If there be any respiratory distress, pain, or insomnia we should not hesitate to give a hypodermic injection of omnopon or morphine. I have never prescribed quinidine, because I think the patient runs sufficient risks without the additional one of poisoning. In these cases there is always a deficiency of calcium, and some absorb it very badly, so you should regularly examine the urine for lime salts. Ringer's solution containing about double the usual amount of calcium chloride and two ounces of the syrup of glucose to the pint is an excellent beverage which should be drunk freely or used for diluting milk.

Enormous numbers of cases of heart disease got rapidly well after the armistice. How is it that since then not only the incidence but the mortality from diseases of the circulatory system has so increased that they have now become, in Osler's language, "the captain of the men of death"? Cardiac failure is now the medical explanation of sudden death; but why does the heart suddenly fail? It is a wonderful self-repairing pump, which can execute an enormous amount of extra work, and will not give out on slight provocation.

In conclusion, I strongly advise you to maintain a healthy and efficient circulatory system, and the heart will take care of itself. Your studies must be along the lines of biophysics and biochemistry. Look at the enormous strides which have been made in physics during the present century. If you wish to move in the van of progress you must educate yourselves; if you trust on the medical schools you are leaning on a broken reed. Associate with

physicists and you will learn something worth knowing. There is one book which I would like you to read, *The Bipolar Theory of Living Processes*, by George W. Crile, the great American surgeon. Be constantly on the lookout for something true, whether new or not. "Receiving a new truth is adding a new sense," though "there are few persons to whom the truth is not a sort of insult." I have often said to my professional brethren, Do not advertise: cure your patients and they will advertise you. It has been often said, with more or less truth, young men kill their patients, old men allow them to die. I counsel you to steer a middle course and keep them alive. Not only keep them alive, but keep them for ever in your debt by the maintenance of their health. Patients are not so ungrateful as some people imagine.

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ACUTE PERFORATION OF THE STOMACH AND DUODENUM.

A CRITICAL REVIEW OF THE RESULTS OF OPERATION.

BY

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FINALITY has by no means been reached in the discussion on the best routine treatment of perforated gastric and duodenal ulcer, and it may therefore not be out of place to consider the results obtained in a series of cases in which the conditions of technique and after-treatment were constant.

The series comprises 154 cases. The method of treatment was to invaginate the perforation by two layers of suture and to strengthen them by an omental graft. At the pylorus and in the duodenum the suture line was made to lie in the transverse axis of the bowel. Immediate gastro-enterostomy was not practised as a routine, and was, in fact, only performed in three of the cases. In one patient the perforation was converted into a gastrotomy by the insertion of a tube drain. Peritoneal drainage—usually suprapubic—was employed in about one-third of the cases, and more frequently in the earlier than in the later ones. All the patients were admitted to the Manchester Royal Infirmary, and it is to the members of the honorary surgical staff of that hospital that I am indebted for the opportunity to operate upon and report these cases. The series is consecutive in the sense that it includes all those patients whose condition warranted laparotomy and on whom it fell to my lot to operate during the years 1924-27. Their number is one which may perhaps fairly be said to indicate the average results of a uniform method under present-day conditions, when early diagnosis is the rule. It is to general practitioners who make this early diagnosis that any improvement shown in modern mortality figures is largely due.

Symptomatology.

One or two features of the clinical picture merit mention. Many writers—Moynihan¹ most insistently—have emphasized the point that a rapid pulse rate is not necessary for the diagnosis of perforation, yet a normal pulse rate

certainly continues to cause hesitation, which may have disastrous consequences. There may occur an actual slowing of the pulse rate, which has been ascribed by Krecke² to stimulation of the vagus. In 40 of 129 cases of this series in which the pulse rate was recorded it was from 60 to 80 beats per minute. The absence of acceleration is perhaps specially evident during the "delusive interval," which occurs typically, though by no means constantly, between the fifth and twelfth hours after perforation.

Adamson, Oehlecker,³ Morley,³ and others have described shoulder-tip pain as a help in differentiating perforated ulcer from other acute conditions. Of 108 patients in this series in whom this point was investigated, shoulder pain was present in 74 and absent in 34. In only 52, however, was the pain at the point of the shoulder on one or both sides. In the others it occurred in the clavicular region, in the neck, or between the shoulder-blades. De Bruine Ploos van Amstel⁴ places little reliance on this symptom, and it may be admitted that it is neither constant nor pathognomonic. Yet the typical rigidity and dramatic onset may fail, as Cuendet⁵ and others have pointed out. In just such cases I have found shoulder pain a useful and comforting help in deciding on laparotomy.

Continental writers have described a pre-perforation stage with severe and uncontrollable epigastric pain as its main symptom. This is regarded as an absolute indication for surgical intervention, yet Schoemaker⁶ had a patient perforate on the night following a prophylactic gastro-enterostomy. In four of the cases here reported the history suggests that such a pre-perforative stage had existed. But it seems doubtful if this condition is more than an exaggeration of the ordinary "attack of ulcer" which frequently heralds perforation, as it did in 64 out of 77 cases in which a note on this point was made. In 10, perforation was the first sign of the existence of an ulcer.

One visualizes the "perforated" patient as suddenly and completely incapacitated. This is not always the case. After the onset of the excruciating pain, four of these patients walked varying distances of from eighty yards to one mile, three "walked home," one continued to work for a few minutes and then climbed down from a roof, and one drove a motor car for three miles.

Of importance in the matter of workmen's compensation is the influence of strain as a causative factor. In one patient (carcinoma of the stomach) the ulcer gave way