These observations seem to us to be important, first of all because they demonstrate an altered state of the blood which goes far to explain the otherwise inexplicable breathlessness in certain patients who suffer from the condition described as irritable heart. They are important from another standpoint. The temptation to cover our ignorance of the pathology of the malady as a whole by referring many of its symptoms to instability or to irritability of the central nervous system was a powerful one, so long as clear deviations from normality could not be found. Our observations carry us from the abstract to the concrete, and tell us that we deal with an affection in which disordered metabolism plays a conspicuous rôle. If we are inclined hastily to judge the temper of our fellow-men, holding that poorness of spirit and lack of zeal contribute to the histories of physical inefficiency as they are related to us, such findings bid us beware, reminding us that there may be no more potent restraint to the display of spirit than the early conditions of ill health.

THE ESTIMATION OF MYOCARDIAL EFFICIENCY.

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THIS article is based on 2,000 observations made on healthy and diseased hearts during the past five years.

The majority of those made on the "healthy" heart, and the reactions worked out in connexion with them, were carried out on students in the Middlesex Hospital, and to all those gentlemen who so willingly and unselfishly sacrificed their Saturday afternoons in order to climb endless stairs—often to the point of extinction—the writer offers his most grateful and sincere thanks, and assures them that their time was not wasted. In this connexion he would also thank Mr. Dale Richards for his assistance in some of the work. The observations on pathological hearts were carried out partly on my own private patients and partly on cases at the National Hospital for Diseases of the Heart.

The measure of a heart's efficiency is its capacity for doing work, and this is true whether one is dealing with the physiological heart of the healthy young adult, the worn-out heart of the old man, the "super" heart of the well-trained athlete, or the pathological heart, the seat of definite valvular disease, myocardial atonia, inflammation, or degeneration. Furthermore, it must be clearly borne in mind that many hearts work perfectly, exhibiting no defects at all, when the person is at rest, but exhibit serious derangements and reveal definite evidence of myocardial impairment when called upon to do extra work under load. Such defects are usually revealed by the development of irregularities—murmurs, pulsations, etc.—which did not previously exist.

WORK REACTIONS.

(a) The Healthy Heart.

The physiological heart of the healthy young adult responds to increased work by increased contraction—the rate increases, the blood pressure rises, and the respirations increase. The increase in the heart-rate, in the blood pressure and respirations, is gradual, while a definite relationship is still maintained between the pulse-rate and respirations. The rise in the pulse rate, in the blood pressure, and respirations is proportional to the amount of work done, but it is rare in healthy people to be able to raise the heart beat beyond 180 a minute excepting by the most violent forms of exertion.

The height to which the blood pressure rises is, apart from training, etc., largely influenced by age, but for a healthy young adult 220 mm. of mercury may be taken as the limit. On ceasing exercise the heart-rate, blood pressure, and respirations, fall rapidly; the blood pressure usually reaches normal (that is, starting point) before the heart-rate. The respirations being the first to return to normal.

(b) The Athlete's Heart.*

The slow "super heart" of the well-trained athlete also responds to increased work by increased contraction and a raised blood pressure, but whereas the heart of the "ordinarily" trained individual gradually increases in frequency, that of the athlete suddenly "practically" doubles its rate.

(c) The Diseased Heart.

The pathological or diseased heart in which the myocardium is at all impaired responds to increased work, not by increased contraction, but by dilatation, so that, although the frequency is increased (often out of all proportion to the amount of exercise taken), the blood pressure either fails to rise or actually falls, according to the amount of myocardial damage present and the amount of work done. Furthermore, the dyspnoea and general distress are often marked, while the normal pulse-respiration ratio is frequently disturbed. Finally, irregularities of various kinds (such as extrasystoles,† auricular fibrillation, and alternation, etc.), murmurs, or pulsations, not previously present, may make their appearance.

As regards the practical application of the above principles, the methods usually adopted by the writer and found to be quite satisfactory are briefly as follows:

1. The Simple Stair Test.

The patient is weighed and his weight recorded in pounds. He is next made to lie down on a couch, and his pulse-rate, systolic blood pressure (brachial), and respirations recorded as below:

NAME	SEX	AGE	WEIGHT	DATE
	PULSE	B.P.	RESP.	
NORMAL				
AFTER 1ST EXERCISE				
AFTER 2ND EXERCISE				

NOTES:—

He is next made to do a definite amount of work in a given time, his pulse, blood pressure, and respirations again being recorded immediately after his return to the couch. As it is most important to get the readings as quickly as possible, two observers are employed, one standing on either side of the couch; one observer takes the blood pressure (the armlet being left in position during the exercise and the manometer being a fixture on the wall), while the other takes the respirations, and whichever completes his observation first takes the pulse. These are recorded on the card as before. These observations are then repeated periodically—for example, every minute—until pulse, blood pressure, and respirations are normal.

For ordinary purposes a very convenient test is to make the patient raise his body weight 20 ft. in not longer than 30 seconds. This is easily done by making him run up a flight of stairs of the required number. His pulse, blood pressure, and respirations should be normal at the end of three minutes after the exercise, if his myocardium is in good condition. The work done (in foot pounds) is easily obtained by multiplying the body weight (in pounds) by the distance through which it was raised (in feet). For purposes of diagnosis it is not necessary to calculate the actual work done, but if the reaction is to be used for remedial purposes, this is essential. In examining the results obtained, the most important points to pay attention to is whether the blood pressure rises or not immediately after the exercise. For practical purposes the results can be classified as follows:

1. *Good reactions*, when pulse, blood pressure, and respiration all increase on exercise and are normal again at the end of three minutes.

	Pulse.	Blood Pressure.	Respiration.
Normal	116	152	22
After exercise	124	180	24
Three minutes after exercise	116	152	22

W. = 2,580 ft. lb. in 30 seconds.

* The writer is of opinion that different effects are produced on the heart by different kinds of exercise—for example, long distance cycle racing produces quite a different heart from rowing.

† Much difference of opinion exists as to the nature and significance of extrasystoles. The writer definitely holds the view that any heart which shows no extrasystoles when at rest, but systematically develops them on exertion, has a damaged myocardium.

2. *Fair reactions.* These include all cases in which pulse, blood pressure, and respiration go up on exercise, but have not returned to the normal at the end of three minutes. Their general return is, however, along normal lines. It may be noted that the pulse-rate is the one that most usually persists raised, and considerable importance attaches to time for which the increased frequency is maintained.

	Pulse.	Blood Pressure.	Respiration.
Normal	72	120	18
After exercise	88	130	24
Three minutes after exercise...	80	124	20

W. = 2,560 ft. lb. in 30 seconds.

3. *"Bad" reaction,* when the blood pressure fails to rise although the pulse and respiration go up.

	Pulse.	Blood Pressure.	Respiration.
Normal	72	150	20
After exercise	88	150	24
Three minutes after exercise...	80	150	26

W. = 3,080 ft. lb. in 30 seconds.

4. *"Very bad" reaction,* in which the pulse and respiration increase but the blood pressure actually falls. This is almost comparable to the condition known as Weber's paradox in muscle.

	Pulse.	Blood Pressure.	Respiration.
Normal	72	150	20
After exercise	98	130	30
Three minutes after exercise...	100	156	28

W. = 2,940 ft. lb. in 30 seconds.

"Good" reactions are characteristic of well-trained "healthy" hearts, such as occur in those who are physically "fit" and take plenty of outdoor exercise. "Fair" reactions are met with in physiological but poorly trained, atonic, toxæmic, or "out of condition," hearts, such as are met with in persons of sedentary occupations who take little exercise; while "Bad" and "Very bad" reactions are typical of hearts in which the myocardium is damaged either by inflammation, strain, or definite degeneration.

The reaction described above (that is, "the 20 ft. 3 min. stair test") is of the greatest value for the average case, but it must be borne in mind that it is a comparatively mild test, and that a more severe test may be necessary to bring out some of the minor defects which may develop in an otherwise well trained heart; for example, slight local heart strain in a previously well trained and otherwise healthy heart may give a fair reaction to this test, but develop a bad or even a very bad reaction if the exercise be doubled or trebled. The progressive work test, if properly applied will never fail to reveal any myocardial deficiency that may exist.

2. The "Exerciser" Test.

In cases for which the stair test seems likely to be rather severe, the patient is made to raise weights through a definite number of feet at a definite rate per minute. The number of weights and the distance can be easily varied. Weights from 1 to 10 lb. are used, and they are usually raised through a height of 2 ft. The effects are recorded as in the previous tests.

3. The "Inclined Plane" Test.

For most serious cases the patient is simply made to walk up an inclined plane (1 in 8) of a definite length in a certain time, and the effects recorded.

In the institution where the writer treats his own cases the height of the staircases, length of the passages, gradients, etc., are all calculated, and a series of tables

have been prepared, by means of which the amount of work done in any case can be read without any calculations at all being necessary.

4. The Progressive Exercise Reaction.

This test is carried out in exactly the same way as the simple stair test, only the work is continued until the blood pressure ceases to rise. This is the point at which the heart is just about to dilate, and gives an accurate idea of the reserve force of the heart muscle and the extent of the cardiac field. In the healthy "young" heart this point is extremely difficult to obtain, but for practical purposes any heart that will stand its owner repeatedly doing 30,000 ft. lb. of work in nine minutes and be normal again within fifteen minutes may be taken as having a thoroughly sound myocardium.

Although I have succeeded in a young healthy heart in producing transient reduplication of the pulmonary second sound, a pulmonary systolic murmur, epigastric pulsation, a tricuspid murmur, or even displacement of the apex and increase in the cardiac dullness by very violent exercise, I have never yet succeeded in causing a definite fall in blood pressure, and I am exceedingly doubtful if it is possible to damage a young healthy heart by exercise alone. If, however, there is fever, anaemia, toxæmia, inflammation, or other form of damage, however slight, violent exercise may produce very serious effects—for example, strain or dilatation. The above remarks apply only to "young" hearts—that is, up to 30, for, save in exceptional cases, one has to be cautious in subjecting persons above that age to such violent tests. In persons with myocardial damage or inefficiency this point is comparatively easy to obtain. This reaction is not only of value for estimating the efficiency of the myocardium at any particular time, and for comparing its efficiency at different times, thus being of the greatest value in estimating the progress of a lesion, but is also of inestimable value in rational treatment.

The method employed for this purpose is briefly as follows: The patient is exercised till the blood pressure fails to rise, and the work done estimated in foot pounds; 1,000 ft. lb. less than the number obtained is then taken, and the patient made to do this amount (that is, 1,000 ft. lb. less than the work necessary to dilate his heart) of work once or more daily for one week; at the end of this time his field of cardiac response is again estimated; all being well it will have improved. 1,000 ft. lb. less than the number now obtained is taken, and the patient made to do this amount of work for another seven days, and the field again estimated, and so on; this is continued each week until either no further improvement is obtained or the limit, 30,000 ft. lb. in nine minutes, is reached.

In carrying out this method of treatment it is essential (1) that the increase shall be gradual, the prescribed work being done once, twice, or three times daily; (2) that it shall be systematic; and (3) that plenty of rest shall be ensured between the exercise.

I have carried out this line of treatment for many years, and in conclusion would urge no one to adopt it who is not thoroughly familiar with the principles on which it is based, and who has not the time and patience to carry it out in all its tedious details. If carried out properly in suitable cases it is doubtful if there is any more successful kind of treatment. It is not possible at present to "cure heart disease," to dilate stenosed orifices, or repair leaky valves, but it may be possible to get the best out of a defective heart by putting that heart to work under the best possible physiological conditions, and the key to this should be a knowledge of what a normal heart can do, and how it does it.

THE annual meeting of Fellows and Members of the Royal College of Surgeons of England will be held at the College, Lincoln's Inn Fields, on Thursday, November 16th, at 3 p.m.

MESSRS. CASSELL will shortly publish the *Life and Letters of Sir Charles Tupper*. He died towards the end of 1915 at the age of 94, and the book is the record of a long career full of manifold activities. Beginning life as a doctor, Tupper took up politics and became one of the makers of modern Canada. He was at one time Prime Minister of Canada, and the present premier, Sir Robert Borden, appropriately contributes an introduction to the biography.