Observations on the effects of exercise on the temperature and circulation / by C. Handfield Jones.

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OBSERVATIONS

ON THE

EFFECTS OF EXERCISE ON THE TEMPERATURE AND CIRCULATION.

BY

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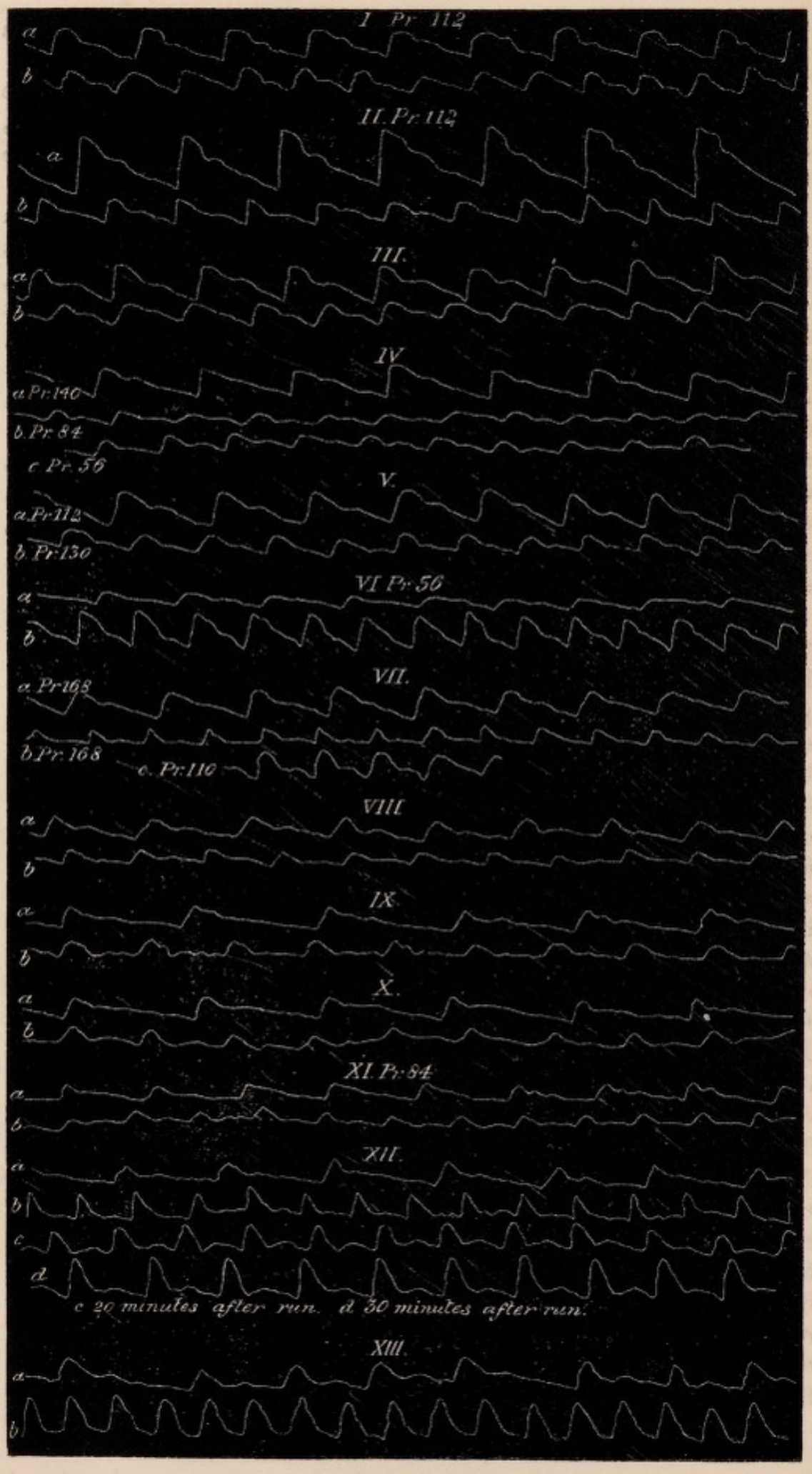
The effects of nervo-muscular exertion on the great functions of circulation and calorification in the human body must always form an interesting subject of observation, not only to the physiologist, but also to the physician, as affording the best available test of the power of the individual frame to endure the strain of disease as well as of fatigue. The effect of bodily exertion on temperature has often been observed. J. Davy found active exertion to raise the temperature 1°·7 F. Obernier found that a quick march of 1½ hour raised the temperature 1°·8 to 2°·16 F. Wunderlich gives the case of an athlete, who, while running a race, suddenly became faint and insensible, and was found soon after to have a temperature of 104°·9 F., a pulse of 128, and some albumen in his urine. In two hours the temperature had fallen to 102°·38. On the second morning the temperature was normal, and remained so, while the urine quickly became free from albumen. Dr. Bathurst Woodman relates the case of a youth who, after walking seventy miles in two days, had a temperature of 105° F., with a pulse of 130, and enormous quantities of lithates in the urine. Another, after similar exertion, was similarly affected. This evidence seems conclusive as to the tendency of severe nervo-muscular exertion to raise the bodily temperature; and it seems that this result is promoted by any existing debility, as in one of Obernier's observations, when the man was out of health, a very fast walk of one hour raised his temperature to 103°·28 F. Wunderlich's and Dr. Woodman's cases are of special interest,

as showing how excessive expenditure of force may generate a condition of high but transitory fever.

My own results, so far as the temperature alone is concerned, are little more than confirmatory of those of others; but the records of the tracings, and of the variations in the cardiac force which were noted at the same time, may add something to their value.

The observations detailed in the accompanying Tables were made on thirteen males, in average good health, during winter or spring weather, about the same hour, 8–10 P.M. The age of I. was 53–54, of II. 36, of VIII. 38, of the others 16 to 26. All bore the exertion well, except IV., who vomited, and was rather prostrate for a short time after. The exercise consisted of a smart run for a mile or two. I have described the sphygmometer with which I measured the force of the pulse in the 'Medical Times and Gazette,' 1871, vol. ii. p. 183. After the run the pulse-rate was generally first observed, then the force necessary to compress the radial artery, then the tracing was taken, and lastly the temperature. Wherever the pressure employed in taking the tracing is not stated, it is to be understood that the same was employed before and after the run.

The result of the Sphygmometer observations was sufficiently constant to indicate the effect generally produced, or tending to be produced, by hard exercise. In eight out of the thirteen cases the artery was compressed by a less force after than it had been before the exercise. The difference in I. was represented by 100 grammes, in III. by 48, in IV. by 112, in V. by 123 (about), in VII. by 56, in VIII. by 116, in X. by 376, in XI. by 100. These figures may be considered to represent the diminution of the force exerted by the left ventricle. The amount of the arterial contraction existing at the time of each observation is perhaps in some measure concerned in the result, but is, I believe, a factor of far less importance than the cardiac contraction. This opinion is borne out by a reference to the tracings of VI., which indicate considerable arterial constriction before the run, and but little after; yet the sphygmometer result is almost the same in both periods. In four instances, II., IX., XII., XIII., the above relation was reversed; the force of the cardiac contraction appeared to be greater after than before the exercise. I can be sure, I think, that this did not depend on erroneous observation. The excess in II. was 56 grammes, in IX. nearly 200, in XII. 30, in XIII. 110 grammes. As these were vigorous individuals, it does not seem improbable that the exercise, which lasted only some ten or fifteen minutes, might excite the heart rather than exhaust it; yet the tracings of II. and IX. do not bear out this view. These four instances seem to me very important, as demonstrating, what might have been suspected on other grounds, how necessary it is to apply the dynamic test in judging of the validity of the circulatory organs. It is not the amount of the force put forth by the heart at a given moment, or the correctness of the


I. Pr. 112
a
b
II. Pr. 112
a
b
III.
a
b
IV.
a Pr. 140
b. Pr. 84
c Pr. 56
V.
a. Pr. 112
b. Pr. 130
VI. Pr. 56
a
b
VII.
a. Pr. 168
b. Pr. 168
c. Pr. 110
VIII.
a
b
IX.
a
b
X.
a
b
XI. Pr. 84
a
b
XII.
a
b
c
d
c 20 minutes after run. d 30 minutes after run.
XIII.
a
b

form of the tracing at the same time, that will enable us to judge how the heart and its vessels will bear the strain of fatigue or of disease. One heart may possess much more reserve force than another, and be able to put forth an increase of energy under the very trial to which the other is succumbing. One man's arteries may possess much more tone and his capillaries more retentive power than another man's.

The Temperature observations are very accordant, showing a rise of ·2° C. (·36° F.) in I. and IV., of ·3° C. (5·°4 F.) in VII., of ·4° C. (·72° F.) in V. and IX., of ·5° C. (·9° F.) in XI. and XIII., of ·6° C. (1°·1 F.) in VI., VIII., and X., and of 1° C. (1°·8 F.) in III. and XII. The general result favours the view that the nerve-centres, which regulate temperature, are enfeebled, though but moderately, by the expenditure of force. The degree of paresis produced varies much in different individuals; but only in two of my subjects did it approach the verge of morbid. The cases, however, previously cited from Wunderlich, Obernier, and Woodman make it very probable that the same cause acting during a longer time would have produced in my instances also decided febrile phenomena; in fact it must be considered remarkable that, in spite of the free sweating which took place, the cool weather, and the lapse of some minutes which occurred before the temperature could be taken, the rise should have been so constant. One remarkable exception, indeed, there is in case II., where the exertion produced actually a fall of ·6° C. (1°·08 F.). This might be explained, as the individual is a man of fine physique, by a similar assumption as was made with respect to the increase of cardiac force, viz. that the regulating centres were stimulated and not depressed by the exertion; but this is doubtful, and I can find no satisfactory explanation. In observation A, at the end of the walk (twenty-two miles) the temperature was notably depressed, being no more than 35°·4, *i. e.* 1°·2 C. (2°·16 F.) below the ordinary temperature of the individual. As food had been taken five hours before, lack of fuel could hardly have been the sole cause, as it seems to have been in Dr. Clifford Allbutt's case; in fact the individual referred to has a temperature of 36°·2 C. (97°·16 F.) after six hours' fast, when quiescent. The tracing, observation A (*b*), was small, but the circulation was fairly good, and the walker did not feel at all chilled. The contrast in this instance between the effects of short but severe exertion and prolonged moderate exertion is very marked. The former raised the temperature of the same man on one occasion ·6° C. (1°·08 F.), the latter depressed it just twice as much.

The Pulse-rate was doubled or more in II., IV., and V., and increased to a less amount in the others. The reason usually assigned for this acceleration, viz. that the blood arrives in greater quantity at the heart because of the pressure exerted on the veins by the contracting muscles, appears to me by no means satisfactory; for if this were the real cause, the heart's action ought to be equally accelerated, or nearly so, in all persons, irrespective of their vital condition. Such, however, is by no

means the fact; it is well known that a person in good condition will do a given piece of work with far less acceleration of pulse than one who is untrained. Thus a Londoner, in ascending a steep Surrey hill heavily weighted, had his pulse raised from 78 (while sitting still) to 120; but a countryman, of rather stronger build, performed the same work with much less acceleration. His pulse was 90 after he had walked to the bottom of the hill, 96 at the top. An anœmic patient of mine had her pulse increased from 78 to 160 by a slight exertion, which, when she was stronger and had more blood, only raised it to 103. Graves observed that the degree of acceleration of the pulse produced by sitting up in bed is a good indication of the extent to which a patient is exhausted. These facts seem to prove, *per exclusionem*, how much the state of the nerve-force has to do with the pulse-rate. Direct experiment (the section of the vagi) makes this still more certain; moreover, as acceleration of the pulse is met with very commonly in conditions of febrile debility, and as a cause of exhaustion was present in all my cases, it does not seem an unreasonable hypothesis, from all these premises, to regard weakening of the regulating action of the vagi on the cardiac nerve-apparatus as the cause of the increased pulse-rate, the vagi nerves or their centres being weakened by the withdrawal of nerve-force to the motor centres of the limbs.

But though I can hardly doubt that this view is in the main correct, harmonizing also as it does with that taken as to the cause of the increased temperature, yet it seems to be opposed by the results obtained with the manometer after division of the vagi. Dr. Sanderson finds that in such experiments the contractions of the heart are sufficiently vigorous to maintain an arterial pressure several inches higher than the normal. But if I may trust my finger and the sphygmometer, the force of the cardiac contractions and the resulting arterial pressure are generally decidedly lowered by active exertion; in fact we know that excessive exertion may produce syncope. I cannot attempt to reconcile this discrepancy. Acceleration of the pulse-rate *per se* seems to have no influence in increasing the intravascular pressure. This conclusion seems to follow from an examination of the sphygmometer records and of the tracings, which, in the majority of instances, show weakening of the cardiac force.

In judging of the Tracings, it may be assumed that in the state of quietude there is a certain amount of nervo-muscular force put forth by the heart and arteries with their nerve-centres, such as can be continuously and without effort produced, and that the amount exhibited in the conducting is duly proportioned to that in the impelling organs. The plan of the circulation evidently requires that the heart's force should greatly exceed that of the arteries, that the latter should yield and dilate under the pressure of the blood-current on their inner surface; and this seen s very constantly to take place. Moderate exercise, which

does not exhaust the heart, as a walk, or holding up a weight for a short time, developes the tracing instead of making it smaller. This is well seen in Obs. D, E, F, G, where the greater rise implies that the artery is relaxed, but the heart not weakened. It is also well seen in cases where the exercise is more severe, as VI. and XIII., but where the heart possesses much reserve force; and is well exemplified in an interesting observation published by Dr. Fraser (Journ. of Anat. and Phys. 1869, iii. p. 128), where a tracing is given showing the effect of hard rowing. The after-tracing is much more ample than the one before, like VI., but differs from this in having a rounder top and a more notched fall, *i. e.* in showing more dicrotism. Where both heart and artery have been weakened, the heart seems to recover sooner than the artery; this is well shown by the tracings taken in a case where nitrite of amyl was inhaled. That taken immediately after the inhalation is irregular, and much smaller than the one taken before; while the third, taken two minutes after the inhalation, is quite remarkable for the height of its rise and the length of the fall preceding the notch. The height of the rise before the amyl was given is ·3 inch, that immediately after is about ·175, while the third is nearly ·6 in. Clearly the artery yielded more on the last occasion to the impelling force of the ventricle than it had done on the first. Expenditure of force seems to produce the same effect. In obs. C, *b*, the tracing taken two or three hours after rowing is much ampler than that taken immediately after. In XII. the tracing taken thirty minutes after run is decidedly ampler than that taken directly after.

Severe exertion seems to exhaust the heart and render it less capable of distending the artery. M. Lortet, in his ascents of Mont Blanc, found his pulse at high elevations febrile, rapid, and so miserable that it was scarcely able to raise the spring of his sphygmograph. In most of my observations the tracing taken as soon as possible after the exercise is smaller than that taken during quiescence. This is very specially the case in IV., where the man was out of condition, and became prostrate and sick after the run; it seems, however, to be the rule, except in individuals whose hearts are gifted with more than usual staying-power, such as in VI. and VIII. Prolonged exertion, though not severe, if I may judge from one observation, also weakens the heart and diminishes the tracing.

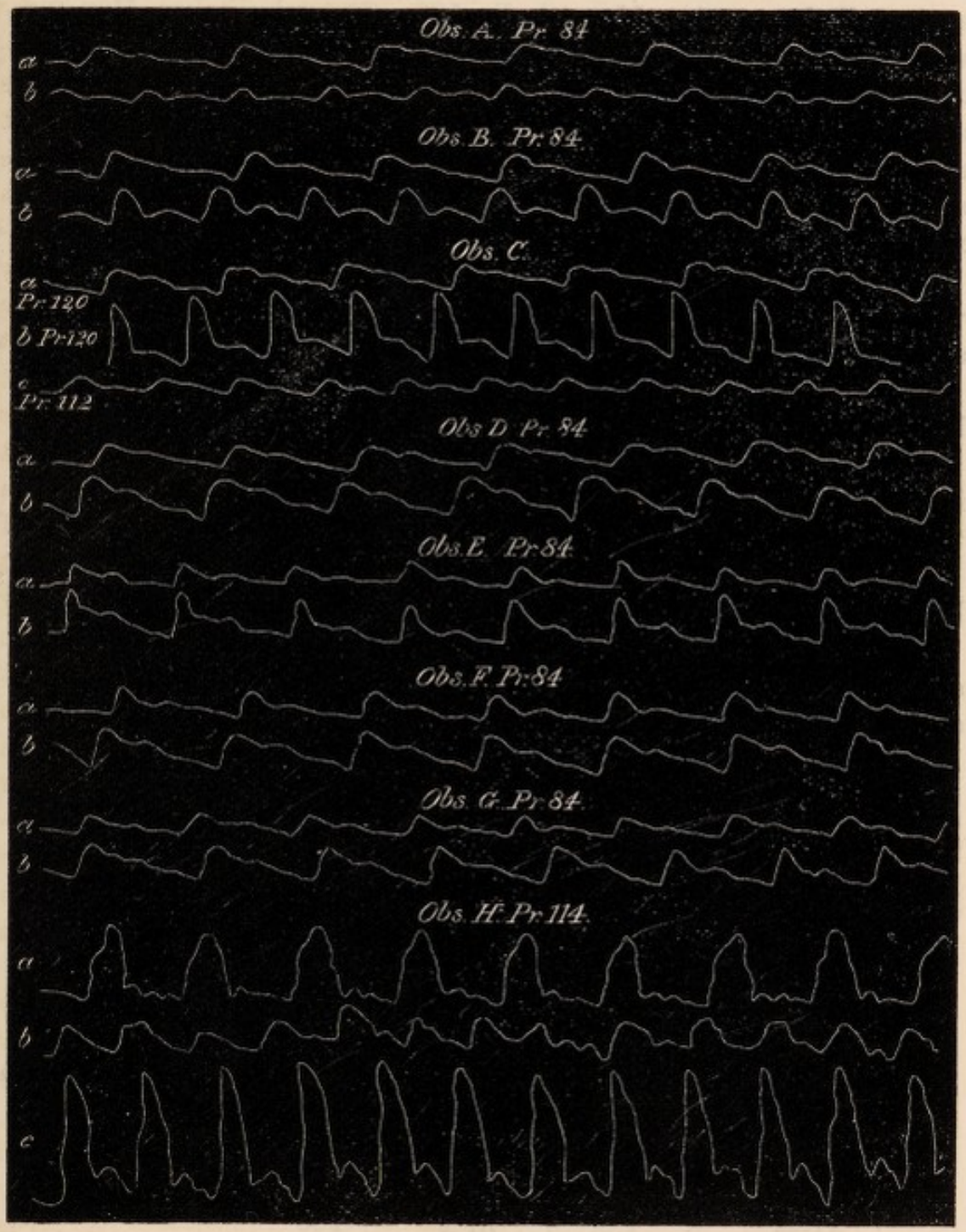
The general conclusion I am inclined to come to is, that the amplitude of the tracing depends partly on the force with which the heart is acting, and partly on the relaxation of the artery. As, however, in all cases of severe exertion there must be considerable expenditure of force, and as at the same time the blood-flow is certainly promoted in the extremities and at the surface, it can hardly be doubted that the arteries, the larger and smaller, are relaxed, and that the size of the tracing is therefore mainly dependent on the amount of cardiac force exerted, which is but slightly opposed by resistance of the arterial coat.

Cases II. and IX. are, however, a great puzzle. Here, especially in II., the tracing is more ample before than after the run; yet the sphygmometer shows that in the latter period the heart is not acting more feebly, but the reverse. This discrepancy is, I fear, not to be got over by the consideration that the height of the ascent does not depend so much on the whole amount of force put forth by the heart in a single contraction as on the amount put forth at a given instant. The artery remaining the same, a powerful contraction of the ventricle taking place gradually may no doubt produce a lower and more sloping rise than a less forcible one, which takes place more suddenly. Dr. Sanderson writes that "suddenness of contraction manifests itself in verticality and amplitude of the primary ascent of the tracing, while in those forms of pulse which correspond to a more gradual mode of contraction the first event is indistinguishable." But the heart in the cases referred to was assuredly not contracting gradually at the time when the second tracings were taken, but sharply and jerkingly. Although the height of the ascent may be no measure of the increased amount of blood in the artery, yet it is, I must think, of the force applied at each systole to the inner surface of the artery and of the expansion of its tube. A sharp flick against the pad of my sphygmometer, which (the pad) is not allowed to move more than a certain distance, will drive the traveller the whole length of the scale, while a pressure less sharply and suddenly applied will not send it nearly so far. In any case, therefore, where, the artery remaining in the same state, or, *à fortiori*, having its contractility lessened, the rise is positively lowered in a tracing as compared with a previous one, I believe that weakening of the cardiac force is indicated; at least this is the only interpretation I can put on my observations. The assumption of a tightened artery would solve the difficulty above stated; but, under the circumstances, this seems so improbable that I cannot think such constriction existed.

The general conclusions as to the effect of exertion on the circulation and temperature which may be deduced from the foregoing observations are these:—

(1) That the heart's force is, in most cases, more or less weakened by great exertion. (2) That the arterial contractility is probably always lessened, even when the exertion is moderate. (3) That after exhaustion the heart recovers sooner than the artery. (4) That the heart's action, in about one third of the cases of severe but brief exertion, is increased in force. (5) That the acceleration of the pulse probably depends chiefly on exhaustion of the vagi. (6) That acceleration of pulse-rate has *per se* no effect in increasing intravascular pressure. (7) That the temperature is usually elevated by exercise from ·36° to 1°·8 F., but in rare instances, or after prolonged toil, may be lowered 1°·08 to 2°·16 F. (8) That the paresis of cardiac and heat-regulating centres, coinciding with consumption of nerve-force in motor centres, shows, that, in some way one centre

is capable of drawing upon another at a time of exigency. (9) That the dynamic test is indispensable to ascertain the lasting power of the heart, the tone of the vessels, and the validity of the nerve-centres regulating the temperature; in fact to gauge the *radical* as distinguished from the *acting* forces. (10) That the capacity to endure fatigue well indicates, *cæteris paribus*, a like power to endure disease well.



Observation A.—A man, æt. 54, walked twenty-two miles, halting at the end of ten for rest and food. The tracing taken on coming in (*b*) was much smaller than that taken before starting (*a*). The temperature some minutes later was only 35°·4 C. (95°·72 F.); an hour later, after rest and food, it was 36°·2 C.=97°·16 F.

Observation B.—Same man. (*a*) Tracing taken, April 16th, while at rest; (*b*) tracing on return home from rowing fifteen miles, *i. e.* about one hour after landing. *b* presents a higher (·15 to 1) and more vertical rise than *a*; the first part of the fall is much steeper, the diastolic expansion is much more marked.

Observation C.—Same man. (*a*) Tracing taken at 1 P.M., having been at rest all the morning, May 4th, Pr. 120; (*b*) tracing taken May 2nd, when feeling exhausted after rowing, Pr. 120; (*c*) tracing taken immediately after a row, Pr. 112: *a* presents a moderate rise, a rounded top, a gradual unnotched descent; *b* a high vertical rise, a blunt but not rounded top, a descent steep in its first half, then horizontal, then rather steep again; *c* is characterized by its smallness, and its low sloping rise.

Observation D.—Same man. (*a*) Tracing taken while at rest, height ·1 in.; (*b*) tracing taken immediately after holding up as long as possible an 8-lb. weight, height ·175 in.

Observation E.—A youth of 18, same experiment as in D. (*a*) Tracing before, height ·1 in.; (*b*) tracing after, height ·2 inch.

Observation F.—Subject of D. (*a*) Tracing taken while at rest in evening, height ·112 inch; (*b*) tracing after a walk of about 2 miles, height ·2 inch.

Observation G.—Youth of 18, same experiment as F. (*a*) Tracing before walk, ·1 inch in height; (*b*) tracing after, height ·175 inch.

Observation H.—Male, æt. 62, affected with Bright's disease and anasarca. (*a*) Tracing before inhalation of nitrite of amyl; (*b*) directly after; (*c*) two minutes after. This experiment was suggested by Dr. Broadbent.

	Right radial compressed by grms.	Axilla temp. °	Rate of pulse.	Rate of respiration.
(I.) Before run ..	350	36·4	75	14
After „ ..	250	36·6	118	52
(II.) Before run ..	174	37	60	
After „ ..	230	36·4	120	
(III.) Before run ..	240	37	84	10
After „ ..	192	38	132	14 (taken too late)
(IV.) Before run ..	250	37·2	66	
After „ ..	138	37·4	148	36
(V.) Before run ..	261	36·8	78	21
After „ ..	138	37·2	166	
(VI.) Before run ..	180	36·6	81	20
After „ ..	192	37·2	120	51
15 min. later	174			
(VII.) Before run ..	366	36·6	78	17
After „ ..	310	36·9	126	44

		Right radial compressed by grms.	Axilla temp.	Rate of pulse.	Rate of respiration.
			°	°	
(VIII.)	Before run ..	232	37,	98·8* 75	16
	After „ ..	116	37·6,	99·8* 110	
(IX.)	Before run ..	308	36·4	60	16
	After „ ..	500	36·8	102	
(X.)	Before run ..	540	36·6	72	
	After „ ..	164	37·2	132	
(XI.)	Before run ..	290	36·5	87	20
	After „ ..	190	37	120	
(XII.)	Before run ..	220	36·6	87	
	After „ ..	250	37·6	124	
		Left radial compressed by			
(XIII.)	Before run ..	165	36·7	60	
	After „ ..	275	37·2	108	

In all the tracings *a* indicates that taken before the run; *b*, *c*, *d* those after.

* Taken by another instrument in mouth.