Physiological observations on the pulsations of the heart, and on its diurnal revolution and excitability / by Dr. Knox.

PHYSIOLOGICAL OBSERVATIONS

ON THE

PULSATIONS OF THE HEART,

AND ON ITS

DIURNAL REVOLUTION AND EXCITABILITY.

By Dr KNOX.

(Read before the Royal Society in Edinburgh.)

(*From the Edinburgh Med. and Surg. Journal, No.* 131.)

More than twenty-two years have elapsed since my attention was first turned to the physiological history of the pulsations of the human heart and arteries. The investigation was an experimental one, and led to conclusions which were deemed satisfactory by many physiologists, and even novel by some; a rare instance of good fortune in respect to them, since the experimenter was still alive.

A very extended criticism, favourable to a degree far beyond the merits of my original papers, appeared in a foreign journal, whose name I have in vain endeavoured to recollect; thus without a reference to it, it is impossible for me to say from recollection, whether the very candid author (a German) of that critique added much that was new to my discoveries, or contented himself merely with their verification; but this I do recollect, that he considered the physiological conclusions as perfectly legitimate. Dr Elliotson, whose name stands so deservedly high as a skilful practical physician and most learned writer, (merits so opposite in character and so difficult to attain) has honoured me with a passing notice in a foot-note to his first edition of a translation of Blumenbach's Physiology, and the opinion he there expresses is, that my doctrines of the pulse, if well founded, are totally subversive of the Cullenian doctrine of simple fever, and, (what I consider more worthy of attention,) opposed to the views of the great Haller.

My first memoir was published in the Edinburgh Medical and Surgical Journal for 1815. The original observations were extremely numerous, made cautiously and without a bias. I shall therefore, having every confidence in them, first, re-state the results then obtained, compare them with what had been done previously and since, and finally, repeat them with views as free of bias as formerly, but matured, it is to be hoped, by an experience of more than twenty years passed exclusively in the exercise of my profession.

It is but doing an act of justice to myself to state, that when I published my original papers on the pulse, I did not feel myself called on to publish more than what I had myself observed. The fashion of adding what is misnamed the "literature" of a subject to my own observations did not prevail then so much as now; and in publishing at that time the result of my inquiries and observations, it did not appear to me necessary to go back to Hippocrates and Galen, Albucasis, Hildanus, Guy de Chauliac, and a host of names so easily quoted even without the trouble of consultation. To me, at that time, it was a question of exceedingly trifling import who first observed, who last; but now that the question of priority has been agitated before a numerous public association,* I cannot pass over altogether in silence this the least profitable part of the inquiry.

In republishing a brief abstract of my first memoir on the pulse, † and the result arrived at, I feel it to be but justice to myself in the first place to compare them with the opinions of a very late observer, who, having gone without doubt unconsciously over the same ground, has arrived at conclusions so strictly resembling my own in most respects, as to give me the greatest confidence in the accuracy of my original observations.

The author I allude to, Dr Graves, who, in a paper "on the effects produced by posture on the frequency and character of the pulse in health and in disease," published in 1830, has reproduced, nearly word for word, the results obtained by me in 1815, and even some of my conjectures; a coincidence extremely satisfactory to me, since it would seem that Dr Graves had never read my memoir. I am indeed aware, that of late it has

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* British Association held at Dublin.

† By "pulse" I mean of course the pulsations of the heart, felt for convenience sake in the radial artery at the wrist. The arteries do not pulsate, so that there is no such thing as arterial pulsation properly speaking. Hence I have often read with surprise a passage in Mr Harison's very excellent work on the arteries, in which the author speaks of "restoring the pulsations of the humeral artery by bending the arm." This excellent anatomist surely must know that neither bending nor extending the arm can affect in any way the course of the blood in the artery. He evidently mistakes the *locomotion* of the artery for the heart's pulsations. There are two or three physiological errors included in the short passage I allude to.

become usual to reprint the views and even original experiments of others without the smallest acknowledgment of the source whence they were derived, and this, too, without putting themselves to the trouble of altering or mystifying the original text, in order to prevent the reader tracing the plagiary to its source ; but I am very far from believing that in the present instance there are any grounds for such a suspicion.

" On the relation subsisting between the time of the Day and various functions of the Body ; and on the manner in which the Pulsations of the Heart and Arteries are affected by Muscular exertion. By Dr KNOX.	" On the Effects produced by Posture on the frequency and character of the Pulse in Health and in Disease. By Dr GRAVES.
Edin. Med. and Surg. Journal, 1815.	*Dublin Medical Journal*, 1830.
" 1*st*, During the morning the mere change of posture from the horizontal to the erect renders the pulse more frequent by about 15 or 20 beats. At midday the increase is about 10, and in the evening 4 or 6."	" 1*st*, In healthy persons, the pulse in the erect posture is more frequent than in the horizontal, from 6 to 15 beats in the minute."
" 2*d*, Were it allowable to apply the rigorous language of calculation to a science which cannot be called exact, we should be disposed to say that such increase in the frequency of the pulse is in a direct ratio of the debility. Hence in fever the slightest change of posture (as from the horizontal to the erect) is often productive of an incredible velocity of the pulse."	" 2*d*, In patients labouring under fever, or in a debilitated state from any other cause, the difference in the frequency of the pulse caused by changing from the horizontal to the erect posture may amount to 30, 40, or 50."
3*d*, The frequency of the pulse on a change of posture is nearly in the direct ratio of the debility of the person. This fact may ultimately prove a valuable asthenometer."	" 3*d*, The greater the debility of the patient the more frequent does his pulse become on change of posture."
" 4*th*, On this principle we may explain satisfactorily, I think, many of the supposed stimulant effects of foxglove, &c."	" 4*th*, Authors who have written concerning the effects of digitalis, &c."

Several other passages might be cited in order to show how exactly the two observers had travelled over the same ground, and, what is satisfactory enough to reflect on, had arrived at precisely the same conclusions. There are two points, however, touched on by Dr Graves which I do not as yet fully understand. First, it is said, that in hypertrophy of the heart there is no differential pulse, or, in plain language, the action of the heart is not quickened by a change of posture. This I at present, for reasons to be shown afterwards, do not believe. The second is a curious experiment made by Dr Graves, to ascertain what would be the effect of counting the pulse of a person placed on the top of his head. I confess I never thought of this posture, being one I could not myself have remained in for an instant without danger of apoplexy ; but there are heads which will stand much bad usage.

Dr Graves further believes, that when the pulse rises on a change of posture from the horizontal to the erect, it is not the muscular exertion which causes this. I adhere to an opposite opinion, for reasons to be more fully explained in the third part of this essay.

My original papers touch on numerous other points in the physiological history of the pulse, with many of which Dr Graves seems to have been unacquainted, such as the diurnal excitability and numerical revolution of the pulse; the effects of powerful and moderate stimulants, of strong exercise, &c.; these, therefore, it becomes unnecessary to notice in this place.

Dr Graves, to whom my researches into the physiology of the human pulse were unknown, seems also to have been unacquainted with the writings of Dr Bryan Robinson, who *originally*, in the strict sense of the term, went carefully over the same ground about a hundred years ago, arriving at results, differing, it is true, in certain respects from those of more modern observers, but yet agreeing with them in many essential points; and therefore anticipating them, as may be remarked I trust without giving offence to any one, by the trifling period of a century. Yet even he does not appear to have been the first who endeavoured to obtain the "constants," if I may say so of the human pulse. M. Quetelet assures us that we owe this to Kepler.* It will be sufficient for our purpose that we adopt Dr Robinson's essays as a starting point. By a brief analysis of his observations and experiments, the subject may readily be brought down almost to the date of my first memoir. From this period questions previously considered as simple were proved to be complex, and a literature was added to the subject, whether profitably or not, I may perhaps consider at some length in a concluding analysis.

Of Dr Bryan Robinson† some might deem it sufficient merely to quote a passage in his preface; "Sir Isaac Newton discovered the causes of muscular motion and secretion; and likewise furnished materials for explaining digestion, nutrition, and respiration." With some this passage would be decisive as to his views, and as to what was to be expected from his writings. But this would be doing his ingenious work great injustice. Though based on false views of the animal economy, it contains several perfectly original observations; above all, it contains the attempt to apply the numerical method to physiology, and this attempt alone merits notice.

Dr Robinson, although agreeable to the fashion of his day,

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* Essai de Physique Sociale, p. 50.

† A Treatise of the Animal Economy. Dublin, 1732.

he considered mathematical reasoning as the soundest basis for a physiology of animal bodies, did not despise or neglect the proofs by experiments.

"I took," says he,* "the pulses in a minute, and measured the lengths of a great number of bodies. I took the pulses when the bodies were sitting, that they all might be situated alike with respect to the horizon; and in the morning before breakfast, that their hearts might be as free as possible from the influences of all disturbing causes; and when I had got a very large stock of observations, I took the means of the pulses." But unfortunately he has not published the tables of observations,—a great neglect in an original observer, thus rendering it impossible for future experimenters to verify his observations. Instead of this he says that he found those means "to be nearly as the biquadrate roots of the cubes of the lengths of the bodies inversely." Language of this kind has happily disappeared from most modern physiological works.

Dr Robinson does, however, give one table to show the near agreement of the pulses from observation with the pulses by the theory.

TABLE I.

Ages in years.	*Length in males.*	*Pulse from observation before breakfast, and sitting.*	*Pulse by theory.*
	72	65	65
	68	67	68
	60	72	74
14	55	77	79
12	51	82	84
9	46	90	91
6	42	97	97
3	35	113	111
2	32	120	119
1	28	126	132
½	25	137	144
0	18	150	184

But the most important conclusions arrived at by Dr Robinson, seem to me to have been drawn from the following series of observations.

TABLE II.

	Morning.							Mean.	Afternoon.									an.
Hours.	8	9	10	11	12	1	2		3	4	5	6	7	8	9	10	11	
Pulse of A.	65	67	70	73	71	69	70	70	77	77	77	77	76	76	74	74	76	76
Pulse of B.	66	71	72	68	69	67	67	68½	75	81	84	81	79	77	78	78	79	78

This table contains "the number of pulses in a minute of two healthy men, A. and B. when sitting from eight in the morning to eleven at night. These numbers are means drawn

* A Treatise of the Animal Economy, Dublin, 1732, p. 132.

from a large number of observations; those of A. from the observations of twelve weeks; those of B. from the observations of three weeks. A. eat his breakfast between nine and ten, B. his before nine; they both dined together at two. B. eat more plentifully than A. and they eat little or no supper."

The conclusions Dr Robinson drew from this series of observations were, that the pulse is slower in the morning than at any other time of the day. The imperfect nature of the details unfortunately renders the table of little use. It is not stated for example how the persons were employed through the course of the day, whether writing, reading, or actively engaged in business. Neither the temperature nor the season of the year have been noted, nor the kind of food, and more especially what drinks were taken. The constant increase of pulse from two to eleven P. M. argues a constant stimulation from some cause or other. Now that cause is not stated.

Dr Robinson was aware of the influence of the mind over the pulse, and the power of exercise to quicken the pulse. "A strong extension of the legs and arms by the power of the will has quickened the pulse twenty beats in a minute, and at the same time made it so low that it could scarcely be felt." This implied, according to my views, that the person was unwell. I know not why modern observers have endeavoured to keep out of view, that the very slightest muscular exertion quickens the pulse; even the action of writing does this to a very great extent; sitting upright, instead of leaning on a desk or table, quickens the pulse; the keeping the spine erect, or allowing it to lean forward, affects it in the same way. These facts will be explained more fully afterwards.

He even seems to have endeavoured to ascertain the ratio of pulse produced by exercise. "The pulses in a minute (he observes) of a man, lying, sitting, standing, walking, at the rate of two miles in an hour, at the rate of four miles in an hour, and running as fast as he could, were 64, 68, 78, 100, 140, and 150 or more." "When a body stands up (he observes) the pulse begins to grow quicker the very instant the body begins to rise."

From this remark, coupled with numerous others to the same tenor throughout Dr Robinson's work, it may be gathered with how little truth, the title of "discoverer of the human differential pulse," can be given to Drs Macdonell, Sanders, or to any other modern observer.* Indeed, nothing can be clearer than Dr Robinson's announcement of these discoveries on the pulse. He attempted to measure the effects, which the depri-

* Transactions of the British Association in Dublin, 1835.

vation of air to the lungs has on the pulse; he experimented on dogs, to ascertain the fact, and observed in himself that on emptying his lungs of air as much as he could, and then stopping his breath, the pulse became small and quick, with a kind of trembling convulsive motion, in less than half a minute of time.

Finally, he compared the number of pulsations and inspirations together, and considered them to be in a minute, as follows:

Pulses,	65	72	116
Inspiration,	17	19	30

From these data I venture to draw the following conclusions:

1*st*, That Dr Bryan Robinson was the discoverer of the "differential pulse in man;" that he described it perfectly, and ascribed it to its real cause.

2*dly*, That he appreciated correctly enough the influence of food, and other disturbing causes of the heart's action, but that he knew nothing of the precise nature of the laws regulating these actions, not having submitted them to any statistical inquiry.

3*dly*, He first suspected and proved indisputably, that from birth to adult age, the rapidity of the pulse constantly declines, and he has given an accurate statistical table to prove this.

4*thly*, He endeavoured to show by the same numercial method that the rapidity of the pulse was inversely as the height of the person; or, to give an example, let A be 5 feet, and let B be 6 feet, then the pulse of A is to that of B. as 72 to 65. But this table is not carefully drawn up, and the conclusions are not legitimate.

5*thly*, He suspected a diurnal movement in the rapidity of the pulse; viz. that it decreased during sleep, and increased from morning until night. With these and several other of his conclusions, I do not agree. We do not here discuss the accuracy or legitimacy of Dr Robinson's conclusions generally, but simply whether or not he was aware of the existence of certain laws respecting the physiology of the pulse, and of the influence of certain disturbing causes. Now nothing is clearer than that he was quite aware of these circumstances.

Lastly, He attempted to ascertain statistically the effects of muscular motion on the pulse *in health;* the ratio of the pulsations to the inspirations and the immediate result on the heart's action, of a temporary deprivation of air.*

With reference to any progress made in this inquiry from Robinson's time to my own I feel a delicacy in making any critical observations. When I published my observations in the

* Some observations were made on the pulse subsequent to those of Robinson, by Falconer and Hewson, but I have failed in procuring the works.

Edinburgh Medical and Surgical Journal, I was quite aware that Dr Sanders had published a work on Consumption of the Lungs, in which the fact of the differential pulse was stated, and the action of various drugs experimented on with a view to the confirmation of certain theoretical views held by the author of that work, with a reference more especially to the therapeutic effects of foxglove : nor was I aware until reading the proceedings of the British Association held in Dublin, that Dr Macdonell claimed, * in opposition to the counter claims of Dr Sanders, a discovery, which in no shape belonged to either, viz. the discovery of the differential pulse, belonging exclusively to Dr Bryan Robinson.

Of any other facts or discoveries published by either of these gentlemen, I am not aware, but shall be most happy to give them a full acknowledgment on their being pointed out to me.

The physiological history of the human pulse presents a number of questions well meriting a solution. In this section it is proposed to analyze the facts accumulated by various observers.

Part II.

The question of an average pulse for any particular age can only be put, at least in this form, by those ignorant to a great extent of the physiology of the pulse. Systematic writers on physiology, by stating such questions and replying to them, display a desire to satisfy the general reader at the expence of truth. The pulse varies every hour of the day and night, and after every meal ; it is extensively influenced by merely rising from the sitting to the erect posture ; and how, under these circumstances, any one can arrive at an average pulse, it is somewhat difficult to imagine. What can be more vague and more unsatisfactory than the following table ; what so unlike correct physiology !

Table I.

Average of the Human Pulse at different ages according to Bryan Robinson.

Age.	*Length in inches.*	*Pulse.*
At birth,	18	150
½ year,	25	137
1 -	28 -	126
2 years,	32 -	120
3 -	35 -	113
6 -	42 -	97
9 -	46 -	90
12 -	51 -	82
14 -	55 -	77
	60 -	72
	68 -	67
	72 -	65

* Dublin Medical Journal, No. 22.

TABLE II.

MAGENDIE.	ELLIOTSON, last edition.	MAYO.
	Before birth, 128	
At birth, 130 to 140		At birth, 140
1 year, 120 to 130	At 1 year, 124	Of 1 year, 120
2 years, 100 to 110	2 years, - 110	From 100 to 110
3 90 to 100	When the first teeth	
7 85 to 90	drop out, - 86	
14 80 to 85	At puberty, - 80	- - 80
Adult age, 75 to 80	At manhood, - 75	Adult from 70 to 75
First old age, 65 to 75	Old age, about 60	- - 60
Confirmed do. 60 to 65	Scarcely found it twice alike.	

It is curious to observe that the oldest writer is not only more minute, but approaches perhaps nearest to the truth.

Such tables as the above are mere copies of each other, and in respect to them I would make the following remarks.

No mention is made how these averages were struck, or if the numbers were drawn from averages at all. I do not believe that they were. We are left to guess, 1*st*, at what time of the day the pulse was noted, and if in all the individuals at the same time of day; 2*dly*, in male or female; 3*dly*, sitting, lying, or standing; 4*thly*, before or after meals; 5*thly*, morning, noon, or night; 6*thly*, whether sleeping or waking.

I hope there is no person who, on considering these remarks carefully, will venture to say that such tables are of any use. It were easy to add to these tables others precisely similar of other compilers, such as Rochoux, Adelon, &c., tending, however, to no other result than that of proving the fact of their having rigorously copied each other.

A little reflection clearly shows that there can be no such thing as an average pulse, unless counted under circumstances precisely similar in all the individuals experimented on; and even then we should only obtain the average for that particular hour and time of day. This would be an average pulse in a certain sense. In the absence, however, of such data, the practical utility of which I question, there still are some, imperfect as they are, which merit attention.

First, M. Paul Dubois makes the pulsations of the fœtal heart to be from 140 to 150, and very often 144.

But it is a remarkable fact, that, in order to arrive at even an attempt at a fair average, we are forced to go back to Dr Robinson's Treatise, written nearly a hundred years ago, and find it to contain the only approach at an analysis of this subject. He gives in table second the average pulse of two men at every hour of the day, (whilst sitting) from 8 A. M. until 11 P. M. taken for several weeks; the mean of these waking hours was, for A. 76; for B. 78. But still there is a meagerness of

detail and a narrowness of observation, rendering it impossible to base on such observations any important conclusion.

The mid-day pulse of 25 young gentlemen, taken between the hours of 12 and 2, in July 1836, was as follows:—

TABLE III.

No.		*Age.*	*Height.*	*Pulse sitting.*	*Pulse standing.*
1	H.	21	5 feet $5\frac{3}{4}$ inch.	66	64
2	H.	22	5 7	74	82
3	R.	27	6 $1\frac{1}{4}$	70	76
4	H.	18	5 6	68	72
5	G.	19	6 0	56	56
6	M'G.	18	5 5	74	76
7	S.	20	5 $7\frac{1}{2}$	68	74
8	W.	20	5 10	82	82
9	T.	17	6 0	96	96
10	E.	17	5 $5\frac{1}{2}$	61	70
11	H.	20	5 0	68	68
12	W.	20	5 5	60	72
13	W.	20	5 8	86	84
14	S.	22	5 6	68	76
15	D.	18	5 8	76	82
16	F.	22	5 $3\frac{1}{2}$	66	68
17	W.	19	5 6	64	64
18	C.	18	5 9	84	92
19	K.	39	5 11	66	74
20	B.	24	5 11	52	56
21	T.	20	5 $11\frac{1}{2}$	69	81
22	D.	17	5 7	84	86
23	S.	22	5 10	82	82
24	M'D.	16	5 8	80	80
25	O.	29	5 $10\frac{1}{2}$	70	72

Mean of ages, 25 Mean Pulse Sitting, 72.4 Standing, 75.4

This table discloses some curious facts in the history of the pulse. So far as could be determined, all these young gentlemen were in good health, with one exception, and yet we find two, in whom the pulse constantly decreased on rising from their seat, and became accelerated on sitting down; being the very reverse of a law, which all physiologists had thought to be universal.

Besides these two in whom the pulse showed so singular a character, there were six others who had no differential pulse, that is, in whom the muscular action required to maintain the body erect did not accelerate the pulse a single beat. It is needless, I hope, to tell the Society that these observations were made with the greatest attention to accuracy.

M. Billard's observations on the pulse of infants were, without doubt, carefully performed, and as infants are less likely to be affected than adults by position, food, &c. they furnish, I think, data to determine the usual rate of the infantile pulse.

In 41 infants from 1 to 10 days old, and all in good health, the pulse was

In 18	less than	80	In 1	less than	130
2	-	80	2	-	145
1	-	89	2	-	150
4	-	100	1	-	180
10	-	110 to 129			

In 36 children from 1 to 2 months.

14	from	80 to 85	5	from	110 to 112
1		60 to 62	2		114
2		90	7		125 to 130
2		94 to 95	3		140–147 to 150

In 20 children from 2 to 3 months.

14	more than	90	2	more than	70
2	-	100	2	-	70 to 80

M. Quetelet gives the average pulse of eighteen boys, and the same number of girls at birth, as follows :—

	Max.	*Min.*	*Med.*
Boys,	165	104	136
Girls,	165	108	135

I have endeavoured to determine the rate of pulsations of the heart in children of different ages, and under different circumstances, as to food, sleep, &c., not so much with a view to any general average of their pulse, as to ascertain if they obeyed the same laws as the adult pulse, but found them too variable to lead to any desided result. I give the following tables, however, as they may be useful to future observers.

TABLE IV.

	1st October 1835.	
Age 7	116	9 A. M. immediately after breakfast.
9	100	
5	124	
43	75	
9	88	12 Noon.
7	92	
5	110	
43 R.K.	67	
	2d October 1835.	
7	112	10 A. M. after breakfast.
8	112	
9	116	
43	74	
	28th September.	
9	100	1 P. M.
7	98	
43	64	
After exercise for two hours.		
9	100	3 P. M. before dinner.
7	100	
43	64	
9	101	5 P. M. immediately after dinner, common fare, a little porter and kipperd salmon, meat and broth.
Age 7	92	
43 RK.	78	
9	90	8 P. M. after very moderate exercise.
5	96	
7	96	
43	70	
9	92	9 P. M. no exercise.
7	93	
43	63	
8 P. M. 13th September.		
7	94	
9	98	
42	64	
½ past 4 after dinner.		
9	103	
7	97	
43	67	
5	98	
9	82	8 P. M.
7	90	
43	58	

Messrs Leuret and Matinie, in their inquiries to determine the

average rate of pulsation in the insane, of both sexes, furnish us with some data for the determination of an average pulse at a certain hour of the day. I shall say nothing at present of the result they arrived at respecting the supposed greater quickness of the pulse in the aged than in those of middle age, reserving this topic for consideration in an after part of this memoir.

TABLE V.*

Alienes,	10 Men	Morning 75	Evening 75
Non alien,	12 do.	do. 68	do. 66
Alienes,	7 Women	Morning 75	Evening 79
Non alien,	6 do.	do. 81	do. 75

These are the data that I am acquainted with in respect to the question of an average pulse.

Part III.

But there are numerous circumstances in the physiological history of the pulse which better merit consideration. These I shall consider in the following order.

1. Is there, or is there not, a "diurnal revolution" of the pulse in respect merely to numbers, independent of stimulation by food or exercise? Now I fancy that this has been completely proved in my first memoir, published more than twenty years ago. But some have asserted that this morning acceleration and evening retardation depends altogether on the use of food and other stimulants, and that, were it not for these, the pulse would not rise early in the morning, and fall towards evening, but would sink constantly. This opinion is altogether incorrect, so that no more need be said about it.

Table showing the differential pulse; observed in Mr S. aged 20, morning and evening, proving a diurnal revolution, both as to numbers, and as to excitability, altogether independent of food or exercise, and proving the morning pulse to be quicker than the evening one.

TABLE VI.

Date. April.	*Hour.*	*Horizontal.*	*Sitting.*	*Standing.*	*Differential.*
5	10 P. M.	53	64	78	25
6	7 A. M.	60	75	90	30
7	7 A. M.	65	80	90	25
8	10 P. M.	57	66	78	21
9	7 A. M.	65	80	90	25
10	10 A. M.	60	82	95	35
	10 P. M.	58	70	76	18

Average differental Pulse.

Morning, 28.7 Evening, 21.3

	Horizontal.	*Sitting.*	*Standing.*
Average morning pulse,	62	78.3	90
Average evening pulse,	56	67	77

The apartments occupied by Mr S. (a gentleman of the

* See Leuret et Mativic.

most regular habits and in excellent health,) seemed to me cold, and exposed to the boisterous westerly winds of this climate. I have no doubt that the temperature of the room had fallen greatly during the night, otherwise the difference between the morning and evening pulse would have been still more marked.

The morning pulse was of course noted before breakfast.

Without doubt, were we to continue long without food, the pulse would first sink, and then become exceedingly quick on the slightest excitement. No one doubts this ; but that the morning pulse is quicker than the evening one, altogether independent of any stimulants, is proved I think beyond a doubt, by these and other tables.

The next question, which is a more important one in many respects, is as to the existence of a diurnal revolution in the excitability of the heart ; by this I mean a varying susceptibility according to the time of day for a healthy powerful action of the heart, when influenced by food, exercise, &c.

The numerous observations detailed throughout this paper, and in my former memoir, published in 1814–15, may, it is hoped, settle this question with unprejudiced persons. The excitability of the heart diminishes regularly from an early hour until late in the evening. Indeed, I have reason to think that, since the publication of my first memoir in 1815, few have doubted this fact, and I beg leave therefore to refer at once to that memoir.

It is extremely difficult to reckon accurately the usual number of inspirations and expirations of any individual, in as much as whenever the mind becomes directed to the respiratory act, it never fails to alter it and render it measured, as if almost voluntary ; nevertheless, the researches of that most accurate and ingenious philosopher, M. Quetelet, merit attention.

From observations made on women he constructed the following :

TABLE VII.

Ages.	*Pulsations.*	*Inspirations.*
0	135	44
15 to 20	78	19
20 to 25	77	17
25 to 30	72	
30 to 50	7.45*	19

TABLE VIII.

	Pulsations.			*Inspirations.*		
	Max.	*Min.*	*Med.*			
In 18 boys at birth,	165	104	136	70	23	44
18 girls at birth,	165	108	135	68	27	44

* An error of the press, I imagine, for 71.45.

In 300 males of different ages.

	Pulsations.			*Inspirations.*		
Ages.	*Max.*	*Min.*	*Med.*	*Max.*	*Min.*	*Med.*
0	165	104	136	70	23	44
5	100	73	88	32		26
10 to 15	98	60	78			
15 to 20	90	57	69.5	24	16	20
20 to 25	98	61	69.7	24	14	18.7
25 to 30	90	59	71	21	15	16
30 to 50	112	56	70	23	11	18.1

M. Quetelet thinks that sleep affects both the pulsations of the heart, and respiration, in corroboration of which he gives the following

TABLE X.

		Pulsations.			*Inspirations.*		
Ages.		*Awake*	*Asleep*	*Rel.*	*Awake*	*Asleep*	*Rel.*
Girl from	3 to 4	102.3	92	1.11	30.2	24.8	1.22
Boy,	4 to 5	93.4	77.3	1.21	29.3	21.5	1.36
Woman,	26 to 27	77.5	67	1.16	27 0	20.8	1.30

But I can nowhere find in the valuable works of M. Quetelet, that he was aware of the effects of position on the pulse; or of its diurnal revolution, or of the diurnal change in its excitablity, and this lessens, I regret to say, the otherwise entire confidence I and all others would be disposed to place in the results arrived at by this profound and ingenious philosopher. In the tables, for example, constructed to determine the influence of sleep on the pulse and respiration, compared with the waking state, no mention is made of the time of day or night, nor of the position of the person whilst awake, whether horizontal, sitting, or standing upright. The pulsation of the person sleeping would, in all probability, be reckoned in the evening at a time when the pulse sinks naturally altogether independent of sleep.

Again he found, that in a male child from 4 to 5 years old. the pulsations whilst asleep were 77.3

Inspirations, 24.5

Whilst awake,

Pulsations, 93.4

Inspirations, 29.3

In the construction of these tables, two great data have been neglected, viz. the position of the person, and the time of the day.

If the pulsations and inspirations were reckoned during the night as an index of the effects of sleep, then the effects of the time of day are mistaken for the effects of sleep; for at midnight the pulse numerically is low in a healthy and stout person, whether asleep or not, and the excitability of the heart is nearly at its zero. Again, the pulse would be counted at one time whilst the person was in a horizontal position, and at another time whilst sitting or even standing. This would al-

so make a difference of 10 or 12 beats, which M. Quetelet has not taken into account. I question much if any effects arise from sleep, excepting of a very trivial nature; but restlessness and watchfulness, arising from any cause when the body ought to sleep and requires it, would produce a highly excited pulse, the result of weakness and temporary ailment.

In this climate the temperature of our rooms often sinks very much during winter, and especially towards the morning;* with the temperature the pulse sinks, and this may be one cause why, as I have just remarked, some have doubted the fact of the pulse being quicker in the morning than towards evening. Haller, it is said, doubted this, but, beyond all question, he was wrong. The greater excitability of the morning and forenoon pulse, over that of the afternoon and evening one, has never been questioned, since first proved by me, so far as I know.

The effects of a cold room in depressing the pulse is such that even the active exercise of writing fails to counteract it.

The following table shews that the pulse remained much depressed under circumstances in which it ought to have risen very much.

TABLE XI.

1st December.	2 A. M. in bed, - - -	60
	5 A. M. sitting and writing for some hours,	60
	There was no fire in the room.	
	6 A. M. still writing, - -	62
	7 A. M. ditto, - - -	60

Here the pulse ought, but for the cold room, to have risen very much, for the action of writing raises the pulse considerably; that of composition still more. Those whose minds are much occupied with business are not *fair* subjects for experiments on the pulse.

The use or abuse of wine and spirituous liquors renders all observations on the pulse inaccurate. These liquors in my opinion, are purely medicinal. Their daily or even frequent use in any climate, or in any quantity, I apprehend to be a great error in regimen, and can never be required. I think them directly opposed to the enjoyment of perfect health and strength.

The restlessness of children, the powerful influence of their

* The thermometer being seldom above 61 or 62 of Fahr. even with a strong fire in the room. I hope it is unnecessary to remark to any medical person that, if he sits before a strong fire, his pulse will rise almost at any time, and that if he sits still in a cold room until his feet feel as if frozen, his pulse will sink proportionally; hence if possible all observations on the pulse ought to be made in summer. I attribute to an inattention to the fact of the coldness of apartments in this country generally during the night and towards morning, why some have thought that there is no diurnal revolution of the pulse as to its numbers, independent of stimulation by food and otherwise; or, in other words, that the pulse will not accelerate towards morning spontaneously.

mind over the heart's action, and their liability to slight ailments, render observations, in respect to their pulse, of little moment. I made at least one hundred carefully noted observations on the pulses of four young persons of different ages, varying from four to ten, and this was the conclusion I drew; that in children of these ages the irregularities of the pulse, proceeding from numerous causes, renders all observations in respect to them of little or no value. I reserve the tables in case they should be afterwards required to prove these conclusions, but their publication at the present moment I consider of no importance. They gave me more trouble than all the rest of the inquiry. One fact was evident, viz. the younger the person the quicker the pulse.

The following is an average table showing the rate of pulsation in four young persons at 4 P. M. and before dinner.

Ages.	*Position.*	*Pulse.*	
9	Sitting	94	27th December, day mild and raining.
7		102	
5		106	
3		108	

Table showing the pulsations of the same young persons (after dinner) at 6 P. M.

Ages.	*Position.*	*Pulse.*
9	Sitting	96
7		106
5		116
3		120

Table XII.

Observations made by Mr S., aged 20; height, 6 feet; quite healthy, and of most regular habits.

Date. 1836. *Mar.*	7 A. M. *In bed.*	9 A. M. *Sitting and writing*	11 A. M. *Sitting at lecture.*	1 P. M. *Standing.*	3 P. M. *Sitting at lecture.*	*Sitting at home.* 5 P. M.	7 P. M.	9 P. M.	11 P. M.
14,	63	110	86	90	78	86	85	63	62
15,	57	111	80	86	75	70	85	75	77
16,	63	108	90	82	76	66	80	74	60
17,	60	104	74	80	76	72	90	76	64
18,	60	100	72	85	74	68	74	72	60
19,	58	72	100	100	78	68	83	72	60
20,	58	76	85	78	80	96	88	68	72
21,	60	92	84	72	68	75	90	75	88
22,	54	100	78	80	72	68	84	68	58
23,	56	100	85	84	72	64	72	66	62
24,	54	96	66	70	69	76	80	71	66
25,	58	106	75	82	70	78	78	68	58
26,	60	80	100	95	85	80	86	78	66
27,	58	70	72	88	75	68	75	74	68
Average,	58.5	94.6	82.6	83	74.9	72.9	73.6	71.6	65.78

* The average morning pulse sitting was 78.3. This was deduced from other observations.

Remarks.—During these observations the meals were,

Breakfast, (coffee) 7½ A. M.
Dinner, . 5½ P. M.
Coffee, . . 8½ P. M.

Neither wine, spirits, nor malt liquors were used.

To determine the effects of exercise on the pulse I made the following observations.

Table XIII.

Showing the rate of sinking of the pulse after walking a mile in a quarter of an hour, counted after intervals of five minutes.

After 1st 5 minutes,	2d do.	3d do.	4th do.	5th do.	6th do.	7th do.
105	93	90	88	88	88	88

Table.—Rate of sinking of the pulse, counted at intervals of five minutes, after walking four miles in one hour.

90	85	70	80	75	77	75

Table XIV.

Shewing the rate of sinking of the pulse at intervals of five minutes, after walking one mile in ten minutes.

After 1st 5 minutes.	2d do.	3d do.	4th do.	5th do.	6th do.	7th do.	8th do.
124	110	100	100	98	97	90	90

These observations were made for me by a young gentleman, (Mr S.) muscular, and seemingly quite healthy.

Exercise quickens the pulse more in the young than in the aged. Walking at the same rate with a young friend of half my age, I found our pulses to be in the following ratio.

Table XV.

	Age.	*Pulse.*	*Pulse.*	*Pulse.*	*Pulse.*
R. K.	42	92	94	104	77
H. R.	19	113	130	130	94

The pulsations were counted at intervals, during a walk of twenty miles, at four miles an hour. Both stood whilst the pulse was reckoned. Towards 5 P. M. I felt more fatigued than he did, and my pulse shewed, by an increased elevation, the effects of debility: R. K. 110; H. R. 117. When the pulse quickens unnaturally on exercise it is a sign of debility.

The following table contains the result of a series of observations made during the course of a day, in which, though only twenty-two miles were walked, the fatigue felt towards the close of the day was very considerable.

The table shows,

1*st*, The effects of exercise when well, and when debilitated by over fatigue.

2*d*, The rate of sinking of the pulse during the day.

3*d*, The great rapidity of the pulse occasioned by debility. It proves that exercise should constantly stop on this side fa-

tigue; when pushed too far, the heart's action changes, and fever to a certain extent is kindled up. Debility, therefore, induced by great fatigue quickens the pulse. Thus, whenever walking is pushed beyond the strength of the individual, the rapid increase in the number of the pulse becomes a measure of the increasing exhaustion: it, in fact, more resembles febrile than healthy excitement.

Table XVI.

	Standing.	Sitting.
9 A. M. before breakfast, - - -	72	64
10 A. M. after ditto, - - -	76	70
11 A. M. having walked two miles at the rate of four per hour, the pulse being counted immediately on sitting, first half minute 53, second do. 60		99
From the 4th to the 5th minute		91
Noon.—After four miles more at the same rate, counted by half minutes;		
Sitting 1st minute, - - -		45
		41—86
do. 3d do. - - -		82
do. 7th do. - - -		81
do. 11th do. - - - -		76
do. 15th do. - - - -		76
Half-past one.—After other four miles at the same rate.		
Standing. first half minute 52, second minute, 46		98
sixth do. 90		
eleventh do. 88		
fifteenth do. 86		
Half-past two, after other three miles at the same rate.		
First half-minute 58, Second do. 53		111
20 minutes past 3, after other four miles at the same rate.		
First half minute 64, Second do. 56		120
6 P. M. After four miles, making in all twenty-two; the latter were performed slowly, the fatigue felt being very great, -	Standing.	119
In twenty minutes lying on a sofa, it fell to		72
But at half-past nine P. M. sitting, it was still		76

General conclusions.—It is certainly much safer for the reader to draw from the foregoing tables and observations whatever conclusions he may think fit, or that he thinks the data will bear out; but least it be said that I have come to no conclusion, (which those are apt to say who have not patience to think for themselves,) I shall venture a few, begging it, however, to be distinctly understood that the observations may themselves warrant quite different ones.

1. The velocity of the heart's action is in the direct ratio of the age of the individual, being quickest in young persons, slowest in the aged. There may be exceptions to this, but they do not affect the general law.

2. There are no data to determine the question of an average pulse for all ages.

3. There is a morning acceleration and an evening retarda-

tion in the number of the pulsation of the heart, independent of any stimulation by food, &c.

4. The excitability of the heart undergoes a daily revolution; that is, food and exercise most affect the heart's action in the morning and during the forenoon, least in the afternoon, and least of all in the evening. Hence we should infer that the pernicious use of spirituous liquors must be greatly aggravated in those who drink before dinner.

5. Sleep does not farther affect the heart's action than by a cessation of all voluntary motion, and by a recumbent position.

6. In weak persons, muscular action excites the action of the heart more powerfully than in strong and healthy individuals; but this does not apply to other stimulants, to wine, for example, or to spirituous liquors.

7. The effects of the position of the body in increasing or diminishing the number of pulsations is solely attributable to the muscular exertion required to maintain the body in the sitting or erect position; the debility may be measured by altering the position of the person from a recumbent to the sitting or to the erect position.

9. The law of the differential pulse is not universal. There are exceptions to be found even in those in perfect health. It is also possible that there may be some in whom the diurnal revolutions of the pulse takes place only in consequence of the use of stimulants. But this has not been proved satisfactorily.

10. The most powerful stimulant to the heart's action is muscular exertion. The febrile pulse never equals this.

11. The law of relation between the inspiration and pulsation of the heart has been stated by M. Quetelet.

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