ON THE

CAPACITY OF THE LUNGS,

AND ON THE

RESPIRATORY FUNCTIONS,

WITH A VIEW OF ESTABLISHING A PRECISE AND EASY METHOD OF DETECTING DISEASE BY THE SPIROMETER.

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Communicated by GEORGE CURSHAM, M.D.,

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1. The subject which I have the honour to bring before this Society, is the consideration of the functions of the organs of respiration, with reference both to health and disease, as deduced from the result of an extensive research.

Before commencing this investigation, it is advisable to ascertain what has been already done by others upon the same subject, in order that the observer may be directed to the points which most require examination, and be enabled to render more apparent the results of his own experiments.

To understand the mechanism and function of the thorax and its contents, demands essentially a knowledge of the circulation of the blood, the composition and pressure of the atmosphere. These subjects were so unknown to the ancients, that we are not surprised to find from their writings how little accurate knowledge they possessed respecting the functions of the respiratory organs.

It is no less curious than instructive to observe, that while their writings teem with refined and absurd hypotheses, how tenacious they were of yielding to the truth when light first began to glimmer upon the subject.

2.—Hippocrates treats largely upon air, water, and situation. Air he reckons as one of the aliments of life; but it was more generally the opinion of the ancients, that a kind of "*vital fire*" was kept up in the heart, and that the blood was tempered in the lungs. Nothing deserving of notice touching the respiratory functions is to be found in the writings of the Greek philosophers. Plato, in his Timeus, says that the "Genii placed the lungs in the neighbourhood of the heart, to keep it cool and in exact obedience."*

Galen, also, considered the chief use of the lungs was to carry off vapours equivalent to smoke from a fire.†

The philosophers of subsequent periods disputed greatly on the subject, and accounted for our well-being as dependent upon fermentations, operations of active spirituous and ethereal particles, as a vital spirit passing from the lungs to the heart and arteries, and becoming animal spirits, which were by this means generated from the air. Others considered the "*vital principle*" a saline vapour, a hot, inflammable, sulphureous spirit, a volatile acid salt; an acrid acid, which preserves the blood in density; and that another use of the lungs was to "*alternate*," or condense, or attenuate, or cool, or heat, or mix, or purify the blood, or shape the blood-globules, or to give configuration to the "finer humours." Others set these views altogether aside, considering that the only use of the lungs was to keep the heart in motion. Such notions prevailed in the time of Descartes, Bertier, Van Helmont, Stevenson, Malpighius, Lister, Vieussenius, Bryan Robinson, Lower, Whytt, Crooke, &c.‡ Galen appears to have held some correct views on the movements of the chest and lungs, viz., that the thorax, distending, draws in the air, and that the lungs follow the dilatations of the chest; this he proves by a direct experiment upon a dog.§ Nevertheless, for 1500 years

* Thomson's Anim. Chem. 1843, p. 604.

† Haller, vol. iii. p. 354.

‡ Haller's Phys. vol. iii. p. 313 *et seq.* Crooke's Anatomical Description of the Body of Man, 4to, 1651, p. 285.

§ Crooke, Op. cit. p. 282.

afterwards, this truth is disputed, and even then not generally believed; so that from Galen to Robert Boyle, naturalists, physicians, and philosophers, explained the simple operation of breathing in three ways:—

First,—" That by the dilatations of the chest, the contiguous air is thrust away, and that, pressing upon the next air to it, and so onwards, the propulsion is continued till the air is '*driven* into the lungs' and so dilates them."

Second,—That the chest is like to a pair of common bellows, " which becomes to be filled because it is dilated."

Third,—" That they are like a bladder, which is therefore dilated because it is filled."

Boyle, the greatest philosopher in his day, adopts the view of the bellows action, and that the lungs are filled with air, because the chest is dilated, and that without the motion of the thorax they would not be filled. " Indeed," says Boyle, " the diaphragm forms the principal instrument of ordinary and gentle respiration, although to restrain respiration (if I may so call it), the intercostal muscles, and perhaps some others, may concur." *

About this time (1667), Richard Lower† correctly describes the respiratory act, and makes a dog breathe like a broken-winded horse, by dividing the phrenic nerve. These truths were not then relished, so that for nearly 100 years afterwards, a number of unfounded hypothetic and contradictory speculations continued to prevail. A Latin tract ‡ appeared in 1671, and was noticed in the 5th volume of the Transactions of the Royal Society, p. 2141, wherein the author contends that the " lungs do *not* follow the motion of the thorax and diaphragm, nor are moved and plied like bellows, and that the diaphragm *cannot* move up and down;" but the breathing operation is accounted for by curious motions, termed " Extrosum, Introsum, Intumescence, Propulsion," &c.

There appears no proof that Galen believed in the exist-

* Boyle's Works, fol. Lond. 1744, vol. i. p. 64.

† Phil. Trans. Abr. vol. i. p. 179.

‡ Novæ Hyp. de Pulm. Motu et Resp. Lond.

ence of air between the pleuræ, but rather the contrary. Yet, down to the 18th century, this error appears to have prevailed, and is maintained by Hoadly, in his Lectures on Respiration, as read before the Royal College of Physicians in 1737, being the Gulstonian Lectures for that year.

The first great epoch in the history of respiration may safely be dated about the year 1628, at which period Harvey published his first work on the circulation of the blood, though at this time his discovery was not thought an epoch; most persons opposed it, others said it was old, and the epithet "*circulator*," in its Latin invidious signification, was applied to him.

At a very remote period, air was known to possess the quality of weight. Aristotle, and other ancient philosophers, expressly speak of the weight of the air. The process of respiration is attributed by an ancient writer to the pressure of the atmosphere forcing air into the lungs.* Galileo was, therefore, fully aware that the atmosphere possessed this property; yet when his attention was so immediately directed to one of the most striking effects of it, he did not see its connection with respiration. It was reserved for his pupil, Torricelli, to discover (1643) the true law of atmospheric pressure; and, as we can find no true cause assigned prior to this date, why air enters the lungs in inspiration, we may date this as the second true step in knowledge bearing upon our subject. Still it will be found that upwards of twenty years after this, Swammerdam adopted the absurd theory of Descartes, that the air was forced into the lungs by its increased density around the breast, occasioned by the dilatations of the thorax, in consequence of the elevation of the ribs.†

In 1667, Hook kept a dog alive by artificial respiration with bellows.‡

Fabricius, in the beginning of the seventeenth century, explained correctly the action and properties of the diaphragm.||

* Lardner's Cyclop. Nat. Phil.-Hydr. and Pneum. p. 247.
† Thomson's Anim. Chem. 1843, p. 605.
‡ Phil. Trans. Abr. vol. i. p. 194.
|| De Respiratione, ii. c. 8.

Malpighi appears to have been the first who described the structure of the apparatus by which the air is distributed through the lungs, and is enabled to act upon the blood.* In 1672, John Templer considers the "structure of the lungs to be a complication of a multitude of the ramifications of the bronchiæ and sanguineous vessels."†

The function and action of the intercostal muscles has probably excited more disputation than any other subject in physiology, and still appears to require fresh investigation.

Borelli is the earliest physiologist (1679) who established an experimental inquiry into the quantity of air received by a single inspiration.‡ Jurin improves upon Borelli. About this time (1708) Dr. James Keill made some correct cubic measurements of the air breathed out of the lungs.§ Then followed Hales, who threw more light upon the doctrine of the air and force of the heart than all his predecessors, yet he was quite ignorant of the use of respiration, and at this period (1733) little was really known on the subject. In 1757 and following years, Black, Rutherford, Lavoisier, Priestley, and Scheele, threw much light upon the matter, by discovering the composition of the atmosphere and respired air. This may be considered as the second great epoch in the history of respiration. From the time of Black to the present period, we may date all the most valuable information we possess upon the subject.

Respiration may, with propriety, be considered under two grand heads, chemical and mechanical; in such an arrangement, our attention is to be directed to the last division.

3.—*Of the mechanical division of respiration.*—The latitude of movement performed by the walls and floor of the thorax to maintain a constant current of air through the lungs, admits of three common degrees of division:—

* Bostock, Elem. Phys. 1836, p. 311. Malpighi, Epist. de Pulmonibus, i.

† Phil. Trans. Abr. vol. ii. p. 5.

‡ De Motu Anim. p. 2, Prop. 81.

§ Tentam. Med.-Phys. p. 80.

First.—Extreme expansion or enlargement.

Second.—Extreme contraction or diminution. And

Third.—An intermediate condition, an ordinary or quiescent state.

These three divisions necessarily imply a difference in the quantity of air respectively drawn in, and thrown out of, the lungs.

4.—Were these movements but two in number, merely extreme expansion and extreme contraction, the quantity of air moved by such efforts would be easy of calculation and expression, but the intermediate effort, or ordinary breathing movement, being so limited, and so perfectly under the control of the will, mental emotions, and the animal functions, renders the calculation of the quantity of air passing through the lungs a very difficult and complicated question.

5.—The quantity of air in the chest, together with those portions which can be added by the thoracic movements, may be arranged, for perspicuity, under five heads, and denominated—

First.—Residual air.

Second.—Reserve air.

Third.—Breathing air.

Fourth.—Complemental air. And

Fifth.—The vital capacity.

6.—First. *The residual air.*—It is well known that the lungs are not capable of being emptied by the most violent muscular effort; therefore, at all times, as long as the lungs maintain their natural structure, during life or death, a certain quantity of air remains in these organs, which is termed "residual air," and over which we have *no* control.

7.—Second. *The reserve air.* — The gentle respiratory movement, regulating the ordinary breathing, is an intermediate effort between extreme voluntary thoracic contraction and dilatation; and hence it is that a portion of air always remains in the lungs *after* the gentle expiration, which *may* be thrown out if required; to this we have applied the name "reserve air."

8.—Third. *The breathing air.*—That portion required to perform the ordinary gentle inspiration and expiration, we term "breathing air."

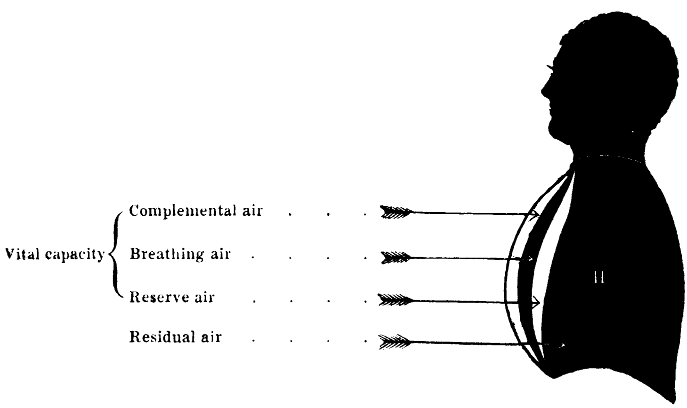
9.—Fourth. *The complemental air* is that portion which *can*, at will, be drawn into the lungs by a violent exertion, (*beyond* the moderate effort of ordinary breathing,) which constitutes the deepest possible inspiration; it is only occasionally added, when required: to this we apply the term "complemental air."

10.—Fifth. *The vital capacity.*—To all these three latter divisions *combined*, being the greatest voluntary expiration, following the deepest inspiration, we apply the term "vital capacity."

This division of the thoracic movements, or portions of air, may be illustrated by the following diagram:—

Diagram 1.

The division of the thoracic movements.



Let that portion marked H represent the "residual air," or air left in the lungs after a complete voluntary expiration; the part next anteriorly marked *white*, the "reserve air," or space for all that air left in the lungs at the termination of an ordinary expiration. The black stripe, the space for the ordinary "breathing air;" the white next anteriorly, the portion for the "complemental air," or extreme deep inspiratory movement; and these three, viz. the complemental, breathing, and reserve airs, conjointly, we style, for convenience, the "vital capacity," in contradistinction to "absolute capacity," which may be considered as the whole *four* divisions combined. The arrows in Diagram 1 point out these different portions or spaces.

11.—A certain latitude of thoracic movement is required to perform the three divisions under our voluntary control—the reserve, the breathing, and complemental spaces. It is also certain that the quantity of air moved or respired in a healthy person will be strictly governed by the extent of this movement, as the degree of mobility of the sides of the common bellows regulates the cubic quantity of air given out at one blast; and whatever affects this mobility of the boundaries of the chest, must modify the cubic measurement of air taken in, or thrown out of, the lungs, in these divisions, either conjointly or separately considered.

Each of these divisions of air has a peculiar character.

12.—*The residual air* is entirely independent of the will, and always present in the chest.

The reserve air, to use a simile, is a "tenant at will."

The breathing air is constantly passing out and in, many times in a minute.

The complemental air is seldom in the chest, and, when present, it is only so for a brief period. Nevertheless, the air commanded by these movements is constantly interchanging or transfusing. Whatever be the quantity of breathing air required for carrying on the aeration necessary for our well-being, the muscular movement demanded to maintain it, is an intermediate effort, just as the black stripe in the diagram No. 1, just referred to, is intermediate, between the white stripes, so that we may consider, at both ends of the ordinary breathing movement, there exists a spare range of voluntary, muscular mobility. Were there no such reserve muscular mobility of the parietes of the thorax, locomotion or any physical or chemical change in the animal economy would be attended with painful dyspnœa and premature death.

13.—The many varieties of the ordinary breathing movement, as frequent or infrequent, quick or slow, regular or irregular, great or small, equal or unequal, easy or difficult, complete or incomplete, long or short, abdominal or costal, with those movements attendant on coughing, laughing, crying, sighing, and vociferating, may be considered as so many modifiers of the ordinary and natural breathing, either infringing upon the complemental and reserve air, or, as it will be recollected each of these respiratory divisions admit of two diametrical movements, *inspiring* or *expiring*, the one act must infringe upon the other. The line of demarcation between the breathing air and the complemental and reserve air is more readily imagined than demonstrated, as it is well known that the ordinary quantity of breathing air is immediately increased or diminished upon the attention being directed towards it, which fact accounts for the enormous discrepancy prevailing amongst authors on this subject.

14.—The calculation of this division of respiration (the breathing air) is encompassed with great difficulties, and would require many years to determine it by direct experiment, in a manner to be available to the physician. Considering, too, the time and care it would *always* require to make the calculation, I am inclined to believe that, according to the present mode of examining patients, it will not in our day be used as a means of diagnosis, nor do I think the subject so important as others about to be mentioned.

15.—The subject of this paper resolves itself under the following heads :—

First.—The quantity of air expelled from the lungs, in connection with other physical observations on the human frame.

Second.—The absolute capacity of the thorax, with cubic, superficial and longitudinal measurements.

Third.—The respiratory movements and mobility of the chest.

Fourth.—The inspiratory and expiratory muscular power.

FIFTH.—The elasticity of the ribs, and estimate of the voluntary respiratory power.

SIXTH.—The effect of decussating, diametrical and oblique power, in reference to the function of the intercostal muscles.

SEVENTH.—General and practical deductions, to detect disease by the spirometer, with the method of its application.

16.—FIRST. *Of the quantity of air expelled from the lungs, in connection with other physical observations on the human frame.*

Many have attempted experiments upon the cubic measurements of respired air, but the discrepancies are such, that, subject to the terms already appointed (5), a brief account of them may be here introduced.

17.—*Observations hitherto made on the residual air.*—Dr. Hales is indefinite upon this subject, in attempting to measure the superficial extent of the air-cells of the lungs: he adds, "a large allowance must be made for remaining air." *

Allen and Pepys found that the lungs of a stout man (5 feet 10 inches) after death, contained 91·134 cubic inches, and allowing 9 cubic inches for error, and 8 cubic inches for correction of temperature, they estimate this bulk of air at 108 cubic inches.†

Davy estimates it at 41 cubic inches.‡ Goodwyn remarks,§ as the result of three experiments upon culprits, this quantity at 272, 250, and 262 cubic inches, but this he considers is too high, and he determines by four other experiments, the mean of which is 109 cubic inches, as the most legitimate inference.

Kite, who writes expressly upon respiration in connection with submersion, is very obscure on this point; he says, "at the end of a common expiration there are 100 cubic inches of air left in the lungs, which will maintain the lungs in a

* Statistics, vol. i. p. 239.

† Phil. Trans. 1809, vol. xcix. p. 404, 428.

‡ Chem. and Philosoph. Researches, p. 410.

§ Connection of Life with Respiration, p. 24 *et seq.*

middle state of dilatation."* This must either mean the reserve air or residual air, or both combined.

Bostock says, "We shall be in no danger of overrating the quantity if we suppose it to be 120 cubic inches." †

Dunglison ‡ gives the estimate of Menzies at 179 cubic inches; Jurine at 220 cubic inches; Fontana at 40; and Cuvier from 100 to 60; Meckel at 52, and even 40 cubic inches,§ which nearly corresponds with Davy. Dr. Herbert, of Gottingen, after a series of experiments on the capacity of the lungs, concludes, that after a forcible expiration, there is "very little air left in them." ||

18.—*Observations hitherto made on the measurement of the reserve air.*—This has received less attention than any other division. Goodwyn entirely omits it, and this omission was pointed out by a physiologist forty years ago, who, at the time, himself omitted taking any notice of the complemental air. Goodwyn remarks as follows: "If, then, we allow 12 cubic inches for a single inspiration, they will be increased to 14 cubic inches when they get into the lungs; therefore the volume of air (residual air), before in the lungs, receives an addition of 14 cubic inches by an ordinary inspiration. But the volume of air in the lungs before an inspiration was 109 cubic inches; hence it will be increased to 123 cubic inches; therefore the dilatation of the lungs after expiration is to their dilatation after inspiration, as 109 to 123."¶ In other words, he adds the residual and breathing air together, omitting the reserve air between them, which would make a difference of 60 or 70 per cent. in this calculation.

Kite calculates this air at 87 cubic inches.** Davy, by an experiment upon himself, at 77 cubic inches.††

According to Mayo, Dr. Menzies appears indefinite upon

* Essays and Observations, Physiol. and Med. 1795, p. 8.

† Elem. of Physiol. 3rd ed. p. 318.

‡ Human Physiol. 2nd ed. vol. ii. p. 90.

§ Manual of Descrip. and Pathol. Anat. vol. ii. p. 448.

|| Bostock, Op. cit. p. 316; and Archives Gén. de Méd. t. xxi. p. 412 *et seq.*

¶ Op. cit. p. 36, 37. ** Op. cit. p. 47, 48. †† Op. cit. p. 410.

this point, by stating "that many individuals were capable, by a forced expiration, of throwing out an additional 70 cubic inches."*

Bostock, from trials upon himself, fixes this at 160 or 170 cubic inches.† Meckel at 110 cubic inches.‡

19.—*Observations hitherto made on the breathing air.*—This has attracted the most attention; but the discrepancies are nearly commensurate with the number of observations, which vary from 3 to 100 cubic inches, as follows:—

	Cubic inches.
Abildgaard, at	3
Abernethy	12
Keutsch, from	6 to 12
Goodwyn	3 and 14
Lavoisier and Seguin	13
Wurzer and Lametherie	8 or 10
Kite, at	17
Davy, at	13 and 17
Allen and Pepys	16·5
Herbst, from	16 to 25
Jurin, at	20
Borelli, from	15 to 40
Herdolt	25 to 29
Dalton, at	30

	Cubic inches.
Fontana, at	35
Richerand, Foland, Gordon, and Cavallo, from	30 to 40
Hales, Jurin, Sauvages, Haller, Ellis, Sömmering, Thomson, Sprengel, Bostock, Chaptal, Bell, Monro, and Blumenbach, at	40
Menzies, from	42 to 46
Reil, from	42 to 100

20.—*Observations hitherto made on the complemental air.*—Davy calculates this air, allowing due correction for temperature, as 119 cubic inches, as determined upon himself.§ Kite says, "at the end of each inspiration, the lungs are capable of containing nearly 200 additional inches." ||

21.—*Observations hitherto made on the "vital capacity."*—Dr. Jurin calculates this at 220 cubic inches, and Hales nearly the same.¶

Davy, experimenting upon himself, and making corrections for temperature, estimates his vital capacity at 213 cubic

* Outlines of Physiol. p. 75 *et seq.*; and Menzies, Op. cit. p. 21.

† Op. cit. p. 316.

‡ Manual of Descrip. Anat. vol. ii. p. 447.

§ Op. cit. p. 410.

|| Op. cit. p. 47.

¶ Hales's Stat. 1732, vol. i. 239.

inches; and he remarks, in a note, "this capacity is probably below the medium—my chest is narrow, measuring in circumference but 29 inches, and my neck rather long and slender." * It is probable the figures 29 are a misprint, instead of 2 feet 9 inches round the chest.

Dr. Thomson examined twelve young men, from 14 to 33 years of age, who varied in their vital capacity from 100 to 250 cubic inches, and the mean of all 186⅓ cubic inches. There is no mention however of the temperature of the respired air. Dr. Thomson himself could expel 193 cubic inches: he remarks, "These experiments were often repeated with the same individual, and the quantity of air which he was able to expel from the lungs was always the same." †

Goodwyn says, "By a full inspiration, after a careful expiration, a man will frequently take into his lungs upwards of 200 cubic inches of air at a single effort." ‡

Kite reckons this "for a moderate sized person as 300 cubic inches." §

Menzies‖ states this as often exceeding 200 cubic inches.

Bostock,¶ corroborated by Dunglison,** though *omitting* the complemental air, estimates this at 210 cubic inches.

Lastly. Thackrah†† justly merits much credit amongst observers upon this subject: he gives the mean of 19 experiments upon soldiers, as 217 cubic inches; and he remarks, "A tall young cornet threw out 295 cubic inches;" and this was the greatest quantity he witnessed. He also examined some shoemakers, and found their average as 182 cubic inches.

It may be possible that some of the foregoing details are incorrectly classified; but the subject of respiration is oftentimes so ambiguously treated, that it is very difficult to arrive

* Op. cit. p. 410. † Thomson's Anim. Chem. 1843, p. 610 *et seq.*
‡ Op. cit. p. 32, note. § Op. cit. p. 48.
‖ Mayo's Outlines of Physiol. p. 76. ¶ Op. cit. p. 321.
** Op. cit. vol. ii. p. 91.
†† Thackrah, on the Effects of Arts, Trades, &c. on Health, p. 21 *et seq.*

at the true meaning of authors. Nevertheless, according to the most careful consideration, I think it may be reduced to the following:—the

21½.—Residual air ranges from	40	to	260	cubic inches.
Reserve air . . .	77	to	170	do.
Breathing air . . .	3	to	100	do.
Complemental air . .	119	to	200	do.
Vital capacity . .	100	to	300	do.

22.—This forms the basis of our present knowledge, from which I can only gather that observers differ. It is possible that all these experiments may be correct; but allowing this, we cannot thence definitely solve the problem respecting the different quantities of air passing through the lungs.

23.—It appears to me, that two circumstances should be taken into account, before any correct conclusions can be drawn from researches of this nature, or I may add from pathological, physiological, and medical inquiries of almost every kind.

1st. With reference to the number of experiments, and

2nd. With reference to collateral observations on the human frame.

24.—All kinds of research may be considered under two heads,—one where the investigation demands for its solution a multitude of experiments, almost without limitation; and the other where a very limited number at once establishes the point. The chemist quickly determines the presence of carbonic acid gas in the breath, by breathing one deep expiration through lime water, when the insoluble carbonate of lime is immediately precipitated: but the physiologist cannot so speedily determine the *quantity* of air that can be given in such an illustration. One experiment establishes the chemical law, whereas thousands are required to determine the physiological question.

25.—With reference to collateral observations, our comprehension of time, space and weight is relative: no isolated observations in nature can be of much value, particularly those made upon the human frame, if strictly considered by themselves. The character of man, mental as well as corporeal, so varies, that were we capable of correctly measuring his different qualities, it is most likely no two individuals could be found presenting the same expression of measure. The medical man, when inquiring into the state of his patient, feels the pulse, auscultates the chest, examines the tongue, observes the countenance, desires to know whether the natural secreting organs are acting in excess or in deficiency; and upon combining these data, he grounds his opinion as to the healthiness of the peculiar organs; and for the most part the more extensive his examination, the better is he able to form a correct diagnosis.

26.—The apparent discrepancies of the respiratory powers, determined by the authors already quoted, are entirely due to the following neglect, viz., that there are no collateral accounts, whether they examined males, females, adults, or children. There are no corrections for temperature, nor for the height, weight, or age of the individuals examined. Omitting these points, the bare facts appear thus discordant. I have examined one man who breathed out of his lungs 80 cubic inches, another 464 cubic inches; therefore, with the same propriety, I might say the vital capacity of man ranges from 80 to 464 cubic inches; but the matter appears more comprehensible when I add that the height of the former was only 3 feet 9 inches, and his weight, 4 st. 9 lbs., while the latter measured 7 feet, and weighed 22 stone; but, what is more remarkable, the discrepancy is entirely removed when I state, that by arithmetically reducing the giant to that of the dwarf, the vital capacity of the dwarf is within half an inch of what it actually was, viz., 79·56 cubic inches by calculation, and 80 cubic inches by direct experiment.

27.—The physician, the pathologist, and the physiologist, will gain but little by weighing or measuring the different organs never so correctly, if he at the same time omit taking the height and weight of the body. It is not likely that the heart, lungs or liver of the stout man could maintain in the same manner the vital energies of the spare man or the tall man. One man is 5 stone, another 25 stone; one 3 feet, another 7 feet. This state of things surely must have a connection with the whole secreting and excreting system. Our structure is like a complicated machine, each portion bearing a certain relation to another, just as the wheels of a clock do to the length of the pendulum; for every length of pendulum demands its own peculiar train of wheels so calculated as to number its oscillation; this oscillation regulates the whole machine. In like manner, the respective development of every man is regulated by some certain and constant capacity or measure of his digestive system as absolutely essential to his respective development, or, we may say, which *regulate* his development. One of the fundamental rules in architecture is "*proportion*," the relation that the whole fabric has to its constituent parts, and which each part has to the complete idea of the whole; for in buildings that are perfect in their kind, from any particular part an architect may form a tolerable judgment of the whole: just in like manner the physiologist, from a portion of the viscera, say an organ, should be able to form a tolerable judgment of the whole man from whom it was taken. From the mere isolated and apparently confused account of the different portions of respired air already mentioned, I am enabled to form some idea of the men examined, though no such account is appended to their experiments. Thus I am entitled to believe that Dr. Jurin and Dr. Hales measured about 5 ft. 8 in., and were between 10 and 11 stone in weight; Davy about 5 ft. 7 in.; Goodwyn under 5 ft. 7 in.; Kite upwards of 6 ft.; Menzies about 5 ft. 5 in.; and Thomson near 5 ft. 7 in.; provided the individuals were in health when the experiments were made.

28.—The individuals I have examined upon the subject of respiration were submitted to the following collateral observations:—

The number of cubic inches given by a full expiration following the deepest inspiration, denominated vital capacity.

The power of the inspiratory muscles.
The power of the expiratory muscles.
The circumference of the chest over the nipples.
The height of the individual.
The weight ditto ditto.
The pulse (sitting).
The number of respirations per minute (sitting).
The age.
The temperature of the breath expired into the Spirometer.
And remarks upon the occupation and general appearance.

29.—*To determine these points,* instruments have been constructed; one for measuring, in cubic inches, the breathed air, which is termed "Spirometer" (208); another for measuring the power of the respiratory muscles; and, lastly, a convenient form of scale and standard for taking the height and weight.

30.—The persons I have examined may be arranged as follows:—

Sailors (merchant service)	121
Fire Brigade of London	82
Metropolitan police	144
Thames ditto	76
Paupers	129
Mixed class (artisans)	370
First Battalion Grenadier Guards	87
Royal Horse Guards (Blue)	59
Chatham recruits	185
Woolwich Marines	573
Pugilists and wrestlers	24
Giants and dwarfs	4
Pressmen . . 30, Compositors . 43 } Printers	73
Draymen	20
Girls	26
Gentlemen	97
Diseased cases	60
Total number	2130

31.—Each of these individuals breathed three consecutive times into the Spirometer, because, either from timidity or inexperience, the first observation is frequently not a correct experiment, but by three observations the point sought for is accurately determined. If more than three observations are consecutively made at one time, the number of cubic inches of air will, from fatigue, generally be found to decrease.

32.—So constant is this deep expiratory power, or quantity of air expired, that I have frequently found adults eighteen months or two years afterwards breathe within two or three cubic inches of the original quantity. I have blown into this instrument hundreds of times, and yet I cannot exceed the original quantity determined five years ago.

33.—This is one of the most simple experiments upon respiration, yet to perform it requires some care and attention; persons will sometimes inspire instead of expire, or partially fill the lungs, or partially empty them: or a nervous person may make a curious compound of the whole; but the operator in a very little time, before twenty cases have passed under his observation, will have become so well acquainted with the method of examining, that he can readily tell when the individual has done his utmost, and so determine the correctness of the experiment. (For the application of the Spirometer, see 208.)

34.—The present object being to determine the vital capacity, we shall inquire what are the relations between this and the collateral observations.

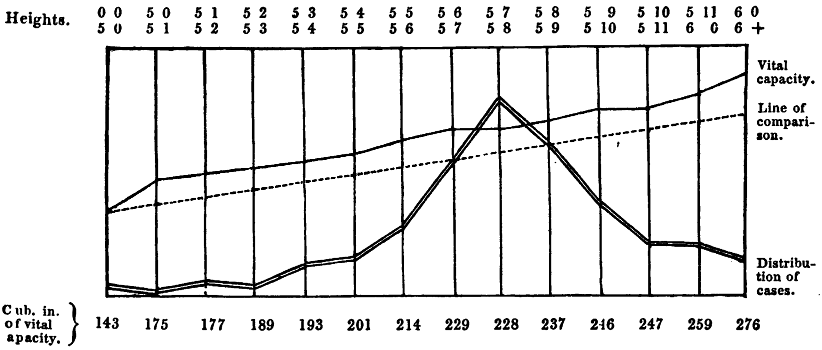
35.—The Vital Capacity of man may be considered as a constant quantity, but this quantity is disturbed directly, or modified by four circumstances:

1st. By Height.	3rdly. By Age.
2ndly. By Weight.	And, 4thly, By Disease.

36.—First. *Of the effect of height.*—The effect of mere height or length of body bears the most marked relation of all these modifiers to the vital capacity, so that I find, if I be allowed to take a man's *height,* I can tell what *quantity* of air he should breathe to constitute him an healthy individual.

DIAGRAM 2.

The vital capacity, in relation to height, on 1923 healthy cases.



To demonstrate this more clearly, let me direct the attention to Diagram No. 2, where a series of perpendicular lines are drawn, which are to indicate different heights: the first line on the left hand is to represent all heights up to, and including, 5 ft.; the second line includes all *from* 5 ft. to, and including, 5 ft. 1 in.; the next *from* 5 ft. 1 in. to, and including, 5 ft. 2 in.; and so on, increasing inch by inch, up to 6 ft.; all above 6 ft. come under the expression of 6 ft. plus.

The continuous horizontal line or curve indicates the relative vital capacity, increasing if it ascends, and decreasing if it descends, as it cuts the perpendicular lines of the different heights. It will be clearly seen that this line ascends nearly in a regular progression as the stature increases from 5 ft. to 6 ft. Therefore the vital capacity in man increases in the same relation. This Diagram is the result of observations upon 1923 cases.

The broken line on Diagram 2 is the line of the arithmetical series, which will be observed to run nearly parallel with the line derived from observation. The figures at the bottom express the mean vital capacity in cubic inches obtained under each of their heights. The double curve, by its ascent and descent, indicates the distribution of the cases, where it will be observed that the greatest number prevailed under 5 ft. 8 in.

37.—The following Table gives a more minute account of the result of this calculation:—

A.—Table of the Mean Vital Capacity of 15 different Classes, or 1923 Cases considered as healthy.

	0 to 5 ft.		5 ft. to 5 ft. 1 in.		5 ft. 1 in. to 5 ft. 2 in.		5 ft. 2 in. to 5 ft. 3 in.		5 ft. 3 in. to 5 ft. 4 in.		5 ft. 4 in. to 5 ft. 5 in.		5 ft. 5 in. to 5 ft. 6 in.		5 ft. 6 in. to 5 ft. 7 in.		5 ft. 7 in. to 5 ft. 8 in.		5 ft. 8 in. to 5 ft. 9 in.		5 ft. 9 in. to 5 ft. 10 in.		5 ft. 10 in. to 5 ft. 11 in.		5 ft. 11 in. to 6 ft.		6 ft. to 6 ft. +	
	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.	Cubic inch.	Cases.
Seamen	151	5	206	1	192	7	219	1	218	10	213	9	217	15	226	14	229	15	239	11	258	18	273	12	270	6	246	2
Fire-brigade	..	..	..	..	..	..	..	..	210	1	208	2	218	20	215	17	231	26	231	20	237	3	260	1	249	2	..	..
Police, Metrop. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	234	4	228	33	226	46	248	22	234	13	262	12	281	11
Ditto, Thames ..	158	1	..	..	..	..	..	..	187	6	206	9	228	9	222	15	246	17	250	10	240	5	257	3	..	..	..	..
Paupers	151	7	166	3	162	10	180	10	174	21	191	20	189	19	210	10	187	9	199	10	262	1	240	3	..	..	..	..
Mixed class	80	1	185	1	162	5	181	5	185	17	191	16	192	20	210	20	222	28	238	16	246	14	238	7	269	9	..	..
Grenadier Guards	..	..	..	..	..	..	168	1	..	..	218	1	199	2	..	..	228	7	233	22	240	16	232	11	253	9	258	14
Compositors	..	..	..	..	176	3	165	2	196	5	188	6	208	7	227	5	215	8	214	6	231	3	..	..	253	1	..	..
Pressmen	..	..	152	1	..	..	..	..	..	..	213	2	203	8	204	3	223	7	245	1	239	4	247	2	..	..	..	..
Draymen	..	..	..	..	..	..	..	..	..	..	..	..	192	1	241	1	218	3	223	4	245	1	261	6	248	4	..	..
Gentlemen......	..	..	..	..	145	1	161	1	156	7	177	9	189	14	208	10	208	18	208	16	236	8	254	12	250	5	262	5
Pugilists, &c.	..	..	..	..	202	1	218	2	218	1	211	4	217	3	267	3	206	1	243	2	273	3	272	5	248	2	..	..
Horse Guards ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	255	30	275	26
Mean of first series	135	14	177	6	173	27	184	22	193	68	208	78	204	118	224	102	220	172	229	164	246	98	254	75	255	82	260	62
Chatham recruits	..	..	167	1	181	1	..	..	189	1	..	..	233	19	238	67	247	38	251	22	266	16	236	2	261	5	284	3
Woolwich marines	..	..	..	..	..	..	..	..	..	..	216	3	223	7	233	99	235	192	240	130	246	75	250	39	263	18	276	9
Miscellaneous ..	..	..	180	1	..	..	194	4	198	4	180	4	196	10	222	18	213	9	230	13	226	12	..	..	259	7	286	6
Total mean under each height ..	135	14	175	8	177	28	189	26	193	73	201	85	214	154	229	286	228	411	237	329	246	201	247	116	259	112	276	80

38.—For convenience, the last Table is arranged as follows, in a form for reference when the Spirometer is used.

B.—Table, Height and Vital Capacity in Arithmetical progression.

Height.	Series from Observations on 1012 cases.	Series from Observations on 1923 cases.	Series in Arithmetical Progression.
	First result.	Second Result.	
5 0 5 2 } 5 1	175·0	176·0	174·0
5 2 5 4 } 5 3	188·5	191·0	190·0
5 4 5 6 } 5 5	206·0	207·0	206·0
5 6 5 8 } 5 7	222·0	228·0	222·0
5 8 5 10 } 5 9	237·5	241·0	238·0
5 10 6 0 } 5 11	254·5	258·0	254·0
Mean of all heights	214·0	217·0	214·0

39.—This relation between the height and the vital capacity is more conspicuously demonstrated on Table B. The first column contains the various heights between 5 ft. and 6 ft., increasing arithmetically two inches at a time, as 1, 3, 5, &c. The two next columns are the result of experiments; the first, at an earlier period of this investigation, upon 1012 persons, the next, at a later period, upon 1923 persons.

40.—The mean of all the men from 5 ft. to 5 ft. 1 in. measured their vital capacity at 175 cubic inches in the first result, and 176 cubic inches on a more extended number in the last result; and the men two inches taller (5 ft. 3 in.) at 188·5 and 191 cubic inches.

41.—It will be observed the vital capacity increases with the height as the eye descends in these columns. The fourth column contains a series of numbers in perfect arithmetical progression, commencing with 174, and increasing 16 every subsequent step. Upon comparing this arithmetical column with those derived from observation, a singularly close resemblance will be observed, particularly if we except the unit figures in each. Therefore it may be said, as these series increase nearly regularly 16 for every two inches of stature upon nearly 2000 cases, the following rule may be deduced:—

42.—"*For every inch of height (from* 5 *ft. to* 6 *ft.) eight additional cubic inches of air, at* 60°, *are given out by a forced expiration.*"

Here is a guide for the operator, and a rule given that will enable us to compare men of different stature and conditions of health one with another.

43.—It will be recollected this difference of the breathing power is solely produced by the effect of stature, every other consideration being sunk in the calculation: this causes the increasing difference between the two series of observations. In the first result, the depressing effect of age lowers the standard of vital capacity, compared with the mean of a different character in the second series, as the Chatham recruits, a *remarkably fine* body of young men, all of whom were correctly examined by Dr. A. Smith, under his personal care and inspection. The Woolwich Marines, are also here included.*

* I would not wish to vouch for the correctness of the observations made upon the *Woolwich Marines*, which were determined by another party, and for two reasons:—First, Because out of 572 men examined, at *all* temperatures, between 62° and 74°, there are—

460 whose capacities terminate with the figure 0.

49 ———————————— 5, which figure is not mentioned on the scale.

Moreover the *corrections* for temperature are also omitted; thus the vital capacity of men taken at the temperature of 62° is *compared* with the vital capacity of other men taken at 74°.

And, Secondly,—The weights and physical character of the men are not

44.—*Of the influence of weight on the vital capacity.*—The effect of weight upon the respiratory system, as here investigated, is neither so intimate nor regular as that of height, yet it must be taken into account. I very soon determined that the weight did affect the vital capacity, when it became remarkable or in excess.

45.—So scanty is our knowledge upon human statistics, that it is very difficult to say what is a man's proper weight, and, therefore, as difficult to detect when his weight, by excess, commences to interfere with the respiratory function.

46.—For the most part it will be found that the weight increases with the height, which I have shown remarkably affects the vital capacity, so that to separate the one effect from the other becomes somewhat difficult.

47.—Suppose we take two men of the same common stature, say 5 feet 8 inches : let the one be 10 stone, and the other 14 stone. It will be evident that one is corpulent or stout, possessing weight in excess, but is the other below par or at par? If 10 stone be considered as par, then every ounce above this is *excess weight*, therefore the 14 stone man is *absolutely* 10 stone, and 4 stone in excess. According to this, every ounce of weight increasing upon 10 stone tends towards corpulency or weight in excess, which must, no doubt, interfere with the respiratory system in a certain fixed relation.

48.—As there does not appear to be any account of what the absolute weight of man should be in relation to stature, it is impossible to say where the weight by excess commences: it is, therefore, only in the extremes of weight that

expressed in figures, but in words, as thus,—52 men are described as "spare," 13 "very spare," 65 "muscular," 132 "stout," 19 "stoutish," 112 "middling," with numerous shades between; nevertheless, the reporter speaks favourably of the Spirometer, "as a means of testing the state of the lungs:" he adds, "that those below 200 were deemed unhealthy:" yet it is not unworthy of remark, that when I make correction for the temperature, the increasing progression between the vital capacity and the height is very regular. —See Table (A.) Woolwich Marines.

we can positively state that there exists an excess or deficiency.

49.—The solution of this apparently simple problem of *what is the weight of a healthy man?* would be a valuable boon to society. The promoters of public health would then have more light thrown upon their researches into the effects of trade and locality on life, than by any other investigation. The medical profession, moreover, would possess a rule to guide them in detecting the inroads of disease.

An investigation so simple, and so valuable, should not be omitted. In making statistical inquiries, the government would do well to consider this, and combine the height and weight with the other questions, when taking the census of the country. We should then see more clearly than we do at present, what trade, occupation, or locality, was most conducive or deleterious to life and health. These points, in all their gradations and ramifications, would afford most useful information on matters connected with the social and commercial welfare of the country.

50.—But to turn from this apparent digression to our immediate inquiry into the effect of weight upon the vital capacity. I find, when I sink the height in a calculation of this kind, that little useful matter is obtained, the effect of height being so predominant that it overwhelms the disturbance produced by weight, as will be seen in the following Table:—

Table of the effect of Weight on the Vital Capacity, the Height being sunk.

Weight.	Vital capacity.		Difference.
7 st. to 8 st.	166	+	21 cub. in.
8 „ 9	187	+	12 „
9 „ 10	199	+	23 „
10 „ 11	222	+	11 „
11 „ 12	233	+	5 „
12 „ 13	238	—	1 „
13 „ 14	237	+	41 „
14 „ 15	278		

I also find the mean vital capacity of 147 men of 11 stone is 225 cubic inches, and that of 32 men of 14 stone only 233 cubic inches, an increase of 8 cubic inches. It also appears that the vital capacity increases from the 7 stone men to the 12 stone men, and then becomes more irregular.

51.—I have made another calculation, keeping the height in view, in the arithmetical increase of inch by inch, and for every 10 lbs. increase by weight. The height extends from 5 ft. to 6 ft. +, and the weight from 100 lbs. to 200 lbs. The observation is made upon 1276 men; the age is here omitted, because, where the numbers are few, certain circumstances the least disturbing must be sunk in the calculation.

D.—Table of the effect of Weight on the Vital Capacity. The Age sunk.

Heights.	lbs. 100 110	Chests.	Cases.	lbs. 110 120	Chests.	Cases.	lbs. 120 130	Chests.	Cases.	lbs. 130 140	Chests.	Cases.	lbs. 140 150	Chests.	Cases.	lbs. 150 160	Chests.	Cases.	lbs. 160 170	Chests.	Cases.	lbs. 170 180	Chests.	Cases.	lbs. 180 190	Chests.	Cases.	lbs. 190 200	Chests.	Cases.
ft. in. ft. in.	c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.		
5 0 to 5 1	177	30	3	187	31	3	141	34	2	140	33	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5 1 to 5 2	178	31	8	156	32	6	180	32	2	174	33	4	196	34	1	..	..	..	..	..	..	150	37	1	..	..	..	..	..	..
5 2 to 5 3	173	30	1	169	31	4	190	32	6	192	34	6	172	33	2	234	37	2	174	37	1	..	..	..	186	40	1	..	..	..
5 3 to 5 4	188	30	3	181	32	6	175	32	17	184	34	20	201	34	13	227	37	2	145	37	1	182	38	7	119	38	2	..	..	..
5 4 to 5 5	168	29	2	168	31	12	182	32	17	190	33	19	206	34	20	207	34	10	181	38	6	..	..	..	..	..	..	..	..	..
5 5 to 5 6	..	..	..	170	33	4	196	33	16	188	33	39	208	34	37	208	35	20	202	36	10	176	38	3	218	38	2	..	..	..
5 6 to 5 7	..	..	..	198	33	3	219	32	31	216	33	40	223	34	60	224	34	25	223	36	13	191	38	5	229	41	2	184	39	3
5 7 to 5 8	..	..	..	228	31	5	215	32	12	197	34	32	221	34	74	209	35	41	227	36	32	214	38	9	224	38	5	182	39	2
5 8 to 5 9	..	..	..	196	33	1	200	31	9	213	33	23	220	35	50	211	35	40	242	36	45	228	37	18	231	38	9	220	39	4
5 9 to 5 10	..	..	..	200	31	1	241	32	3	235	33	10	241	34	22	239	36	30	244	36	32	274	38	15	246	38	7	214	39	5
5 10 to 5 11	..	..	..	195	30	1	185	31	2	208	33	2	254	34	8	238	36	20	217	35	18	248	38	13	278	38	8	237	38	5
5 11 to 6 0	..	..	..	..	..	..	..	..	..	243	33	2	244	35	5	264	36	16	259	36	13	251	37	34	261	38	10	263	41	5
6 0 to 6 +	..	..	..	..	..	..	..	..	..	260	33	2	243	36	2	253	35	4	279	39	11	281	37	17	274	38	16	275	39	10
Total mean..	176	30	17	186	31	46	196	32	117	203	33	201	219	34	294	228	35	210	217	36	182	219	37	112	226	38	62	221	39	35

52.—From this Table it appears the effect of weight on the vital capacity is irregular.

To make the influence as clear as possible, I condense the total mean, as follows, from Table D.

E.—Table reduced from the last, of the effect of Weight on the Vital Capacity.

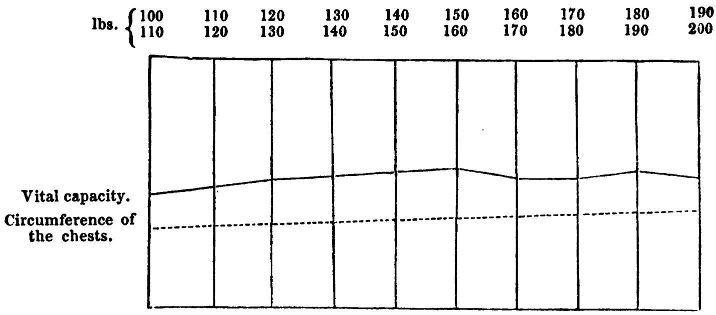
Weight in lbs.	Cubic inches for every 10 lbs.	Cubic inches for every 20 lbs.	Difference.
100 110	176	181	+ 18
110 120	186		
120 130	196	199	+ 24
130 140	203		
140 150	219	223	– 5
150 160	228		
160 170	217	218	+ 5
170 180	219		
180 190	226	223	
190 200	221		

53.—It seems the vital capacity increases 42 cubic inches with the weight from 100 lbs. to 155 lbs., and from 155 lbs. to 200 lbs. the effect is balanced by minus 5 and plus 5 cubic inches. In the first division (Table E.) there is an increase of 42 cubic inches; in the second division there is a decrease of 42 cubic inches in the vital capacity.

54.—I have delineated this by curves upon Diagram 3 (next page). The continuous line will be seen at first to ascend as it passes over the perpendicular lines, which lines represent the respective cases increasing in weight in decimal portions of 10 lbs. at a time, from 100 to 200 lbs. This curve will be seen as highest at 160 lbs., and from thence it continues nearly horizontal as it passes the remaining heights up to 200 lbs.

DIAGRAM 3.

The effect of weight on the vital capacity.



55.—According to this, it may be said that the vital capacity increases nearly in the ratio of 1 cubic inch per lb., from 105 to 155 lbs., and that, from 155 to 200 lbs., this increase is overpowered, and there is a loss of 39·5 cubic inches as the effect of weight.* Therefore, all weight under 11½ stone does not interfere with the vital capacity, but, on the contrary, it increases with the weight up to this point, but above this weight, as far as our Table goes (viz. to 14 stone), the weight interferes with the vital capacity, preventing this increasing progression in the relation of rather more than 1 cubic inch to the lb.

56.—The influence of weight, as shown by these Tables, is calculated for the height of 5 feet 6 inches, being the mean of all heights between 5 feet and 6 feet; therefore to this height *only* these points of weight (from 11½ stone to 14 stone) refer.

The weight of man naturally increases with his stature,

* This loss of 39·5 cubic inches must be added to 2·5 cubic inches, the mean of the 5 minus and 5 plus cubic inches, in the 2nd division, Table E., making a total loss of 42 cubic inches.

therefore the relation between the weight and the vital capacity must also vary at different heights.

57.—If it be granted that, at the height of 5 feet 6 inches, the vital capacity commences to be affected, when the weight exceeds 11½ stone, it cannot be expected, when a man is 6 inches taller, (whose natural weight considerably exceeds 11½ stone,) that from this *same* point his vital capacity is affected in the relation of 1 cubic inch per lb. Accordingly, I have calculated the weights, in relation to all heights, from the cases I examined, together with 1554 cases of men in the prime of life, obligingly furnished me by Mr. Brent, whose weights I believe to be correct, and the following is the result:—

58.—F.—Table of the Mean Weight in relation to Height on 3000 Males,* at the middle period of life (from 15 to 40), including the Weight of their Clothes.†

Heights.	No. of Cases.	Gross weight in lbs.	Mean weight in lbs.
ft. in. ft. in.			
4 6 to 5 0	26	2399	92·26
5 0 to 5 1	17	1964	115·52
5 1 to 5 2	36	4476	124·33
5 2 to 5 3	43	5497	127·86
5 3 to 5 4	88	12145	138·01
5 4 to 5 5	126	17537	139·17
5 5 to 5 6	214	31016	144·93
5 6 to 5 7	316	45598	144·29
5 7 to 5 8	379	57822	152·59
5 8 to 5 9	468	73835	157·76
5 9 to 5 10	368	61238	166·40
5 10 to 5 11	348	59460	170·86
5 11 to 6 0	245	43475	177·45
6 0 to 6 +	326	71283	218·66
Total . . .	3000	487745	147·86

* The classes whence these cases are taken are as follows:—Sailors, firemen, metropolitan police, Thames police, paupers, artizans, labourers, Grenadier Guards, Horse Guards, printers, draymen, wrestlers, pugilists, Oxford and Cambridge rowers, London watermen, cricketers, pedestrians, and gentlemen.

† M. Quetelet says, the average weight of the clothes at different ages is one-eighteenth of the total weight of the male body, and one-twenty-fourth part of the total weight of the female.—Quetetet sur l'Homme, &c.

From this Table it will be seen that the weight increases with the height, as from 92 lbs. to 218 lbs. To make the progression more apparent, I arrange the above in another order.

G.—Table of the difference of Weight, in relation to Stature, on 2648 Males, taken from the last Table.

Exact stature.			Weight in lbs.	Weight in lbs. more exactly.	Difference of weight in lbs.
ft.	in.	In inches.			
5	1	61	120	119·9	+ 6·2
5	2	62	126	126·1	+ 6·8
5	3	63	133	132·9	+ 5·7
5	4	64	139	138·6	+ 3·5
5	5	65	142	142·1	+ 2·5
5	6	66	145	144·6	+ 3·8
5	7	67	148	148·4	+ 6·8
5	8	68	155	155·2	+ 6·9
5	9	69	162	162·1	+ 6·5
5	10	70	169	168·6	+ 5·6
5	11	71	174	174·2	

This is determined by adding the mean weight from Table F., of the men from 5 feet to 5 feet 2 inches (the mean of which height is exactly 5 feet 1 inch), together, and taking the mean of that, which will be found 119·9 lbs.; and the next from 5 feet 1 inch to 5 feet 3 inches, taking their mean as 126·1 lbs. and so on.

59.—The range of stature from 5 feet 1 inch, to 5 feet 11 inches, is 10 inches: and the weight rises from 119·9 lbs. to 174·2 lbs., or 54·3 lbs., or 5·43 lbs. to every inch of stature.

To subdivide this range of height it may be said—

	lbs.		ft. in.		ft. in.
Their rise is	6·2	from	5 1	to	5 4
———	3·3	—	5 4	—	5 7
———	6·5	—	5 7	—	5 11

The inequality from 5 feet 4 inches to 5 feet 7 inches may disappear when the observations are extended: at present it may be stated generally that the weight increases 6·5 lbs. (or 6½ lbs.) for every inch of stature from 5 feet

7 inches to 6 feet, and 6·2 lbs. for every inch of stature from 5 feet 1 inch to 5 feet 4 inches: from 5 feet 4 inches to 5 feet 7 inches the increase is nearly half of 6·5, or 3·3 lbs. for every inch.

At 5 feet 8 inches, or 68 inches, of stature, the weight is 155·2 lbs., or nearly 11 stone; from this, as a starting point, the weight at any other height may (so far as our limited observations warrant) be readily calculated. For instance:—

The weight is, at the height of 5 feet 8 inches, $\frac{155 \cdot 2}{68} = 2 \cdot 282$ lbs. for every inch of stature, or 27·38 lbs. for every foot. As a pound of water = 27·727 cubic inches, the bulk of the human body may be represented by a cylinder of water of 68 inches high, and nearly 9 inches (8·9761) in diameter.

From geometry it is shown that the bulk or weight of symmetrical bodies is as the 3rd power (cubes) of any of the diameters: thus, if a person 67 inches high weigh 148·44 lbs., a person 69 inches high should weigh,

$$\left(\frac{69}{67}\right)^3 \times 148 \cdot 44 = \frac{69 \times 69 \times 69}{67 \times 67 \times 67} \times 148 \cdot 44 = \frac{328509}{300763} \times 148 \cdot 44 = 162 \cdot 14 \text{ lbs.}$$

The weight at that height from *observation* was 162·08 lbs., and from *calculation* 162·14 lbs.

Taking the height from 67 to 71 inches, we have as follows:—

H.—Table of the Calculated Weight, compared with the Observed Weight.

Height in inches.	Weight determined by calculation.	Weight determined by direct observation.
	lbs.	lbs.
67	148·8	148·4
68	155·2	155·2
69	162·1	162·1
70	169·3	168·6
71	176·6	174·2

The lower heights are heavier than they should be, the higher, lighter than they should be, symmetrically. The weights indeed vary as the 2·75th power of the height, and not as the 3rd power.

60.—To bring these two last Tables E. and G. upon weight, to bear upon the statement (55) of the effect of weight on the respiratory function, I may venture to infer that as the calculation of the effect of weight is made at the fixed height of 5 feet 6 inches, and that, at this height, a man must attain the weight of 155 lbs. before his vital capacity is diminished, and that the average weight of this height is 145 lbs., therefore he may exceed his average weight by 10 lbs., or 7 per cent. before his vital capacity is effected by weight. Presuming this last opinion, we may probably be allowed to consider that the starting point from whence we may commence to count *excess* weight as interfering with the vital capacity as 7 per cent. upon the mean weights given in Table G. For example :—The weight of the men of 5 feet 1 inch is 119·9 lbs., add to this 7 per cent. (8·395 lbs.) weight, making 128·2 lbs.; again, the tallest men, 5 feet 11 inches, weigh 174·2 lbs., to this add 7 per cent. (12·2 lbs.), making 186·4 lbs.: therefore, at the height of 5 feet 1 inch, a man must exceed 128 lbs., or 9 stone 2 lbs., and the 5 feet 11 inch man 186 lbs. or 13 stone 4 lbs., before weight may be expected to diminish the vital capacity, in the relation of 1 cubic inch per pound for the next 35 lbs., or 2½ stone, being the limit of the calculation. I believe it will be found, that when the weight exceeds this limit, the vital capacity will considerably decrease, and that probably in a geometrical relation, from the mere circumstance of fat preventing the mobility of the thoracic boundaries.

I have not found the vital capacity altered in healthy men below the mean weight.

From what has been said, the examination of corpulent persons must not be compared with those not corpulent, though in all other respects the same.

This effect of weight in diminishing respiration, need not in the least confound the observer, when examining a case with reference to phthisis, or any other chest disease; the use of the scales, together with other physical observations, will sufficiently protect him from such an error.

61.—*Of the effect of age upon the vital capacity.*—As might be anticipated, age affects the vital capacity, but not so remarkably as the two preceding causes; the first calculation, however, upon 1088 cases, did not make it apparent. This was in consequence of examining such a mixed multitude at all ages. But, after the examination of the Chatham recruits, I found the effect of age was very marked, causing the difference between the two columns in Table B., page 157, on 1012 and 1923 cases. This is more fully seen in Table A., where the vital capacity of every class is compared. I now subjoin a Table of the effect of age on the vital capacity, the *weight* in this case being sunk.

I.—Table of the effect of Age upon the Vital Capacity, on 1775 Healthy Cases.

Heights.	Age, 15 to 20.	Cases.	Chests.	Age, 20 to 25.	Cases.	Chests.	Age, 25 to 30.	Cases.	Chests.	Age, 30 to 35.	Cases.	Chests.	Age, 35 to 40.	Cases.	Chests.	Age, 40 to 45.	Cases.	Chests.	Age, 45 to 50.	Cases.	Chests.	Age, 50 to 55.	Cases.	Chests.	Age, 55 to 60.	Cases.	Chests.	Age, 60 to 65.	Cases.	Chests.
ft. in. ft. in.	c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.			c. in.		
5 0 to 5 1	231	3	30	182	1	31	219	1	31	..	..	..	152	1	31	150	1	34	..	..	..	..	..	..	130	1	34	141	2	34
5 1 5 2	188	9	32	178	4	32	164	3	33	..	..	..	173	1	33	125	3	34	..	..	..	..	..	..	145	1	35	167	1	33
5 2 5 3	178	5	31	205	5	34	226	1	36	213	4	34	..	..	..	194	1	36	168	3	34	..	..	..	167	2	30	179	2	34
5 3 5 4	198	10	31	191	11	33	199	9	35	206	6	34	192	6	32	179	9	34	185	2	36	198	6	35	156	5	35	146	3	36
5 4 5 5	185	13	31	208	15	33	203	11	33	210	8	34	191	6	35	193	7	35	163	6	33	188	7	35	202	4	33	173	3	31
5 5 5 6	214	17	34	221	38	34	209	16	35	215	15	34	203	19	34	207	7	35	183	8	37	165	8	35	178	3	36	165	4	36
5 6 5 7	243	65	34	230	78	33	235	56	35	232	28	36	206	25	35	216	12	35	216	11	34	155	2	40	197	4	38	198	3	34
5 7 5 8	242	81	34	224	116	34	232	79	35	232	53	35	217	34	34	209	15	36	189	9	36	183	4	36	213	4	38	160	3	35
5 8 5 9	241	38	35	239	107	35	222	64	35	228	57	35	220	27	35	223	16	36	204	8	37	211	6	35	194	1	38	215	3	38
5 9 5 10	252	27	35	247	67	34	249	48	36	254	25	38	275	13	37	225	11	38	203	3	39	210	2	35	203	3	40	..	..	..
5 10 5 11	218	6	33	262	29	36	242	34	35	257	26	36	242	22	37	237	4	37	220	3	35	220	1	38	219	2	35	270	1	41
5 11 6 0	254	9	35	264	20	36	272	25	37	239	20	37	265	17	37	264	7	39	240	2	35	209	1	41	..	..	..	200	1	38
6 0 6 +	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total mean ..	220	283	33	220	491	34	222	347	34	228	242	35	212	171	34	201	93	35	197	55	35	193	37	36	182	30	36	183	26	35

Treating this Table upon the same system as the last, it is here reduced as follows:—

J.—Table arranged from the last Table, reduced to decimal periods of time.

Age.	Cubic inches.	Cases.	Circumference of chest.	Vital capacity for every 10 years.	Difference.
15 to 20	220	283	34	220	+ 5
20 to 25	220	491	34		
25 to 30	222	347	34	225	−19
30 to 35	228	242	35		
35 to 40	212	171	34	206	−11
40 to 45	201	93	35		
45 to 50	197	55	35	195	−13
50 to 55	193	37	36		
55 to 60	182	30	36	182	
60 to 65	183	26	35		
Mean of all ages	205·8	1775	35		

62.—The column of "difference" points out the effect of age. This agrees with our experience: time as we see affects the animal kingdom in a two-fold manner, first bringing it to perfection, and then deteriorating it.

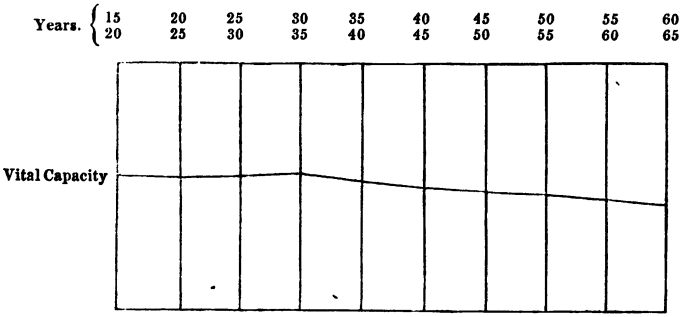
63.—From 15 to 35 years of age, the vital capacity is increased, and from 35 to 65 years of age, it is decreased in the progression of 19, 11, and 13 cubic inches.

In the same manner as before, I have illustrated this by lines on Diagram 4 (next page), where the curve of the vital capacity will be seen to descend after it passes the perpendicular line of 35 years of age, and keeps declining as it cuts all the preceding lines of quinquennial periods of age, down to 65.

64.—The vital capacity therefore, from this Table (Table J.), increases with the age up to 30 years, and from 30 to 60 it decreases 43 cubic inches, or 1·43 (nearly 1½ cubic inches) per year, or 7 cubic inches in 5 years, or 14½ cubic inches in 10 years.

Diagram 4.

The effect of age on the vital capacity.



65.—This quantity being small, it will readily be imagined that such an effect upon a small number of men of all ages would escape detection.

66.—It will doubtless have occurred to the minds of some present, Has the size of the chest no relation to the vital capacity? I shall refer to this more particularly under the next head, on the absolute capacity of the thorax; nevertheless, a remark upon the effect of the circumference will not here be out of place.

67.—Contrary to what I ever expected, (and agreeable to the opinion of others,) I do not find there exists any direct relation between the circumference of the chest and the vital capacity.

68.—I have found by one of my Tables upon the circumference of the chest, (not here introduced,) that the mean vital capacity of 11 men of 5 feet 8 inches whose chests measure 35 inches in circumference over the nipples, is 235 cubic inches, while that of 10 men of the same height, whose chests are 38 inches (3 inches more), is only 226, being 9 cubic inches less.

69.—The following Table is an epitome of this calculation.

K.—Table of Circumference of the Chest, in relation to the Vital Capacity, in 994 cases.

Circumference of chest.	Mean cubic inches.	No. of cases.	Cubic inches difference.
inches.			
30 to 30½	200	14	–13
30½ to 31	187	20	+18
31 to 31½	206	21	–10
31½ to 32	196	35	+ 1
32 to 32½	197	32	– 7
32½ to 33	204	50	– 2
33 to 33½	202	44	0
33½ to 34	202	63	+11
34 to 34½	213	70	+ 4
34½ to 35	217	78	– 2
35 to 35½	215	71	+14
35½ to 36	229	74	–10
36 to 36½	219	59	+ 2
36½ to 37	221	97	+18
37 to 37½	239	59	– 4
37½ to 38	235	57	–13
38 to 38½	222	41	+ 8
38½ to 39	230	40	– 6
39 to 39½	224	18	+ 2
39½ to 40	228	37	–11
40 to 40½	217	14	0

The height is here kept in view, and is calculated at 5 feet 6½ inches. Nothing regular presents itself, probably owing to the weight being sunk, as fat on the chest will both increase its dimensions, and decrease its vital capacity; therefore I find on looking into the calculations, such apparent discrepancies as 15 men of 5 feet 9 inches having a vital capacity of 233 cubic inches; while 11 men of the same height, but whose chests measured 3 inches larger, had only a vital capacity of 232 cubic inches, and the mean of 14 men of 30½ inches circumference 204 cubic inches; while that of 14 men of 40½ inches only 217 cubic inches; and one out of these had a vital capacity of 57 cubic inches below that of the men whose chests were 10 inches less. Hence the *absolute* breadth of the chest is not a direct or ready guide to estimate the vital capacity.

70.—I may here mention, that it was in consequence of so often witnessing tall, thin, and narrow-chested men, breathing so much more air than broad-chested men, that I was first led to consider and combine the height with these observations. I examined nearly 200 men with no satisfactory result, until I introduced the height into the examination, which so completely arranged the whole research in the order I have described.

Nevertheless, under certain circumstances the size of the chest will be found to affect the vital capacity, as when we have a thoracic mobility of 3 inches on a 40-inch chest, we shall find a greater vital capacity than with the same mobility on a smaller chest.

71.—The most remarkable relation of the circumference of the chest is to that of the *Weight,* with which it increases in an *exact* arithmetical progression of 1 inch for every 10 lbs.

It will be seen in Table D., page 162, that the men of 100 and 110 lbs. have chests of 30 inches, and those of the next 10 lbs. increase 1 inch; and so on in perfect progression. I have illustrated this on Diagram 3, page 164, with a dotted line, where the increase will be seen perfectly regular as it passes over the perpendicular lines of increasing weights.

72.—To conclude this portion of the inquiry, it may be added, that the healthy vital capacity is chiefly affected by three circumstances—height, weight, and age.

By height, an increase of 8 cubic inches at 60° for every inch of height (42).

By weight (at the height of 5 feet 6 inches), the vital capacity is not affected under 161 lbs., or 11½ stone; but above this point it diminishes the vital capacity in the relation of 1 cubic inch per lb. up to 196 lbs., or 14 stone. And at other heights, between 5 feet 1 inch and 5 feet 11 inches, ten per cent. may be added to the mean height, (given in Table G., p. 166,) before we allow the weight to affect the vital capacity in the relation of 1 cubic inch per lb.

By age (from 35 to 65), a decrease of rather more than 1 cubic inch per year.

73.—SECONDLY. *Of the absolute capacity of the thorax, with cubic, superficial, and longitudinal measurements.*—Finding that different men breathed such different quantities of air, and that too chiefly in relation to height (which principally depends upon the length of the legs), I was anxious to determine by direct experiment, whether the depth or breadth of the thorax corresponded with the increase of stature. Finding little light thrown on this question in the physiological works I consulted, I had recourse to the following series of experiments to solve the point. For the opportunity of making these, I am indebted to the kindness of my friend, Dr. Boyd, of the Marylebone Infirmary.

74.—I examined 20 bodies; 6 females and 14 males. I made an opening over the sternum into the chest, just large enough to admit my hand; the heart and lungs were removed, the cavity was then perfectly filled with plaster of Paris, the sternum returned into its original position, and kept there until the plaster was hard, then the abdomen was opened, the diaphragm removed, and the cast withdrawn from the cavity of the thorax. (The casts were exhibited before the Society.)

75.—The height and weight of the body were previously taken, also the weight of the heart and lungs together, with the cause of death. These casts I have submitted to numerous measurements, as their length, breadth, depth, superficial and cubic dimensions, the whole of which are, on the next page, arranged in a tabular form. I believe this method will furnish us with correct measurements of the thorax.

76.—There required no precautions as some think for fixing the diaphragm; I believe it did not vary from its natural position, the abdominal viscera keeping it perfectly fixed on one side, which I found was not disturbed by the weight of the plaster: there is *more* danger to be apprehended from the elasticity of the ribs, which becomes very apparent when once we cut through these elastic arches; therefore the opening was kept as small as possible,—a necessary precaution to be observed.

L.—Table of Various Measurements of the Thorax, 14 Males and 6 Females. The Weights and Heights are given without their Dress.

Initials.	Sex.	Age.	Height.		Weight.	Weight of the Heart.	Weight of Right Lung.	Weight of Left Lung.	External Circumference over Nipples.	Internal Circumference, largest part.	Ditto of Right Half of Chest.	Ditto, Left ditto.	Superficial Inches of Internal Walls of the Chest.
		yrs.	ft.	in.	lbs.	oz.	oz.	oz.	in.	in.	in.	in.	s. in.
E.	Fem.	30	4	6	72	9	16 1/2	21	32	24 1/2	14 1/4	13 3/4	198
D.	Fem.	55	5	1	50	6	7 1/2	9 1/2	25 1/2	23 1/2	13 1/2	12 1/2	237
K.	Fem.	62	5	3	85	9 3/4	22 3/4	13 3/4	28 1/4	23	12 1/4	12 1/2	189
V.	Fem.	23	5	4	109	9 3/4	15 3/4	9 3/4	29 3/4	24	13 1/4	13	180
G.	Fem.	39	5	4	125	18 3/4	28	18	32	24 1/2	14 1/4	14	247
M.	Fem.	35	5	6	125	17	22	33	31	23 3/4	13	13 1/4	220
Z.	Male	74	5	4	74	8 3/4	30	18 3/4	28 3/4	26 3/4	14 3/4	13 7/8	262
F.	Male	43	5	5	77	9 1/4	36	31 1/2	27 1/2	25 1/4	14	13 7/8	280
H.	Male	38	5	5	107	10 1/2	22 1/2	20 1/2	32	29	16 1/2	15 1/4	258
T.	Male	80	5	6	82	11 1/2	18 1/2	17 1/2	30	26 3/4	15	14 1/2	234
L.	Male	40	5	6	92	8 1/4	27	33 1/4	29	25	14 1/4	13	234
B.	Male	78	5	6 1/4	145	24	21	17	35	30 1/2	16 1/4	17	283
C.	Male	39	5	7	94	10 1/2	49 1/2	37	31 1/2	27 1/4	15	14	277
S.	Male	77	5	7	157	21	24	24	39	31	16 1/2	16 1/4	318
O.	Male	48	5	8	92	15 1/2	43	29 1/2	30 1/2	28	15 1/8	17 7/8	276
X. C.	Male	21	5	8	154	11 1/2	8 1/2	8 1/4	*34 1/2	27	14 1/2	14 5/8	206
I.	Male	87	5	9	109	14 1/4	28 1/2	23	33 1/2	27 1/2	15 1/2	15	253
N. H.	Male	22	5	10	133	—	—	—	†30 1/2	25 1/4	13 1/2	14 1/4	219
P.	Male	40	5	10	98	13 1/2	45	35 3/4	31 3/4	27 3/4	14 1/4	16 1/4	271
A.	Male	28	5	10	132	13 3/4	45	33 1/4	35 3/4	31	16 3/4	17	241

Initials.	Superficial Inches of the Diaphragm.	Superficial Inches of the entire Cavity of Chest.	Cubic Inches of Right Half of Chest.	Cubic Inches of Left ditto.	Ditto of Entire Cavity of Chest.	Depth of Right Lung from Apex to Arch of Diaphragm.	Depth of Left Lung from Apex to Arch of Diaphragm.	Depth from between Apices to Arch of Diaphragm.	Depth from before, backwards, of Right Lung (Maximum).	Depth from before, backwards, of Left Lung (Maximum).	Greatest Depth from before, backwards, of Chest.	Distance between Sternum and bodies of Dorsal Vertebræ.	Projection of Dorsal Vertebræ into Cavity of Thorax.	Greatest Breadth of Cavity of Thorax.	The Highest Apex of Lungs.	Distance between Centre of Apices of Lungs.	Vital Capacity of such Chests.
	s. in.	s. in.	c. in.	c. in.	c. in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	lung.	in.	c. in.
E.	39	238	107	128	235	7	7 6/8	7	6	6 1/2	6 6/8	4 5/8	2 7/8	7 5/8	Right	2 1/4	170
D.	30	267	127	140	267	8 6/8	9 1/8	7 7/8	6 1/2	6	6 1/8	4 3/8	2 1/2	7 6/8	Right	1 6/8	174
K.	30	219	95	129	224	6 3/8	7 5/8	7 3/8	5 3/8	5 1/4	6	4 1/4	2 1/4	8	Left	2 1/2	190
V.	38	218	84	111	195	6 1/8	7 6/8	6 1/4	5 1/2	5 3/8	5 6/8	3 5/8	2 1/4	8 3/8	Right	2 5/8	197
G.	36	283	129	206	335	7 3/8	8	6 5/8	6 3/8	6	6 3/4	4 1/8	2 5/8	8 1/4	Left	2 1/4	197
M.	36	257	112	136	248	7 7/8	8 5/8	7 6/8	4 6/8	5 3/8	5 7/8	3 3/8	2 1/2	8 5/8	Right	2 5/8	194
Z.	41	303	167	168	335	7 7/8	10 1/2	9 5/8	6 1/8	6 1/4	6 3/8	4	2 1/4	9 1/2	Left	3	161
F.	36	316	155	200	355	8 7/8	9 1/2	8 1/2	6 5/8	6 3/8	6 6/8	4 5/8	2 3/8	8 6/10	Left	2 6/8	188
H.	53	311	170	186	356	7 3/4	8 1/2	7 1/4	7	6 3/8	7 1/2	4 3/4	3	9 5/8	Right	2 1/2	189
T.	47	281	143	157	300	6 7/8	8 1/8	6	7 1/8	7 1/10	7 1/8	5	2 1/4	8 3/10	Left	3 3/4	188
L.	41	275	138	148	286	8	8 1/2	8 5/8	5 7/8	5 1/8	7 5/8	4 1/8	1 7/8	9	Right	2 1/2	188
B.	56	339	157	222	379	7 1/2	8	8 6/8	7 6/8	7 6/8	8 1/4	5 1/8	2 6/8	9 7/8	Right	3 3/8	213
C.	44	321	165	183	348	8 6/8	8 5/8	8 3/8	5 3/4	6 1/4	6 7/8	4 1/4	2 3/4	9 5/8	Right	2 7/8	210
S.	57	375	215	242	457	7 6/8	8 6/8	8	7 1/2	7 7/8	7 1/2	5	2 1/4	11 1/4	Same	3 1/4	202
O.	43	319	157	217	374	8 3/8	10 3/8	8	6	5 7/8	6 1/4	3 7/8	2 3/10	10 3/8	Right	2 3/4	202
X. C.	51	257	105	140	245	6 1/4	7 3/8	6	6	6 1/4	6 1/2	4 1/8	2 1/2	9 7/8	Right	2 6/8	202
I.	46	299	163	179	342	8	8 6/8	7 1/2	6 3/8	6 7/8	6 1/2	4	2 1/2	9 6/8	Left	2 6/8	224
N. H.	37	256	110	138	248	8	8 3/8	7 6/8	5 3/8	5 5/8	5 7/8	3 1/4	2 1/2	9 1/4	Same	2 3/4	233
P.	50	321	144	205	349	7 5/8	9 1/8	7 5/8	6 1/4	6 7/8	7 1/8	4 1/4	2 1/2	9 7/8	Left	2 1/8	240
A.	63	304	132	163	295	7 1/8	7 1/2	7 1/2	6 7/8	6 7/8	7 1/2	4 3/4	2 7/8	11	Left	3	238

* Alive, 33.

† Alive, 33.

77.—Those who are curious may consult this last Table upon a variety of subjects in connection with the chest and the stature, points most valuable to the medical practitioner. I shall here only mention one or two of the most important in connection with our subject.

78.—The cases are arranged according to their height; the shortest placed first and the tallest last, with a regular gradation between. It will be seen that the cubic contents of the chest in no way correspond with the height, therefore the increasing quantity of air, which I term the vital capacity, is *not* regulated by the size of the chest. The shortest man, only 5 feet 4 inches, has a thorax of 335 cubic inches, and the three tallest men, of 5 feet 10 inches, a mean *absolute* capacity of 297 cubic inches, being 38 cubic inches *less* than that of the man 6 inches shorter.

This Table is more valuable, from my having had an opportunity of examining two men when living, and a few days subsequently, of taking a cast of their chests an hour after death. The one cast is marked X. C., 5 feet 8 inches, the cubic measurement of which I found to be 245 cubic inches, and his vital capacity, determined when alive, was 202 cubic inches at 60°, which, if calculated at 98° degrees as the supposed temperature of the body, brings it to about 218 cubic inches; but there was the commencement of tubercle in his lung, or he would otherwise have breathed (with the corrections for temperature) about 235 cubic inches; only 10 cubic inches short of the whole space allotted for these organs.

79.—The next case was a man still taller, marked N. H., whose height was 5 feet 10 inches; the cubic contents of his chest I found to be 248 cubic inches, while his vital capacity (making corrections for temperature) was 251 cubic inches, at 98°—three inches *more than the whole space of the thorax* appropriated for the heart and lungs.

80.—I may here introduce the statement of a curious circumstance, in connection with this last case, which will be found to militate against a generally-received opinion.

It will be recollected that the vital capacity is obtained by a maximum movement of the boundaries of the chest, and it is believed that this thoracic movement is impeded by adhesions between the pleuræ. In this case I can affirm, that though the mobility of his chest exceeded the whole space or cubic contents of that cavity, there was not one square inch of the pleuræ but what was *firmly united.* His lungs in other respects were healthy in structure, and his vital capacity scarcely diminished.

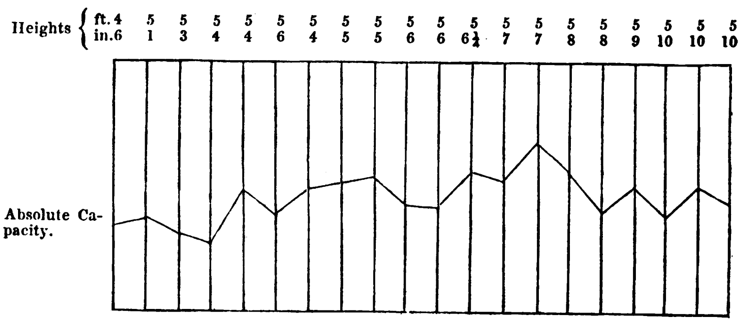
81.—From this it would appear that adhesions of the pleuræ do *not* prevent the freedom of the respiratory movement, and I think we may here generalise from a single case. I believe the movement of the ribs in respiration is *so* closely followed by the lungs, that a perfect union between the two does not interfere with this function.

82.—The largest chest amongst these casts is that marked S.: the height of the man was only 5 feet 8 inches, yet he possessed an *absolute* capacity of 457 cubic inches, and according to his conformation and general dimensions his vital capacity might be expected as 202 cubic inches: this is not one half of the absolute capacity.

The range of the absolute capacity of the cases from whence these casts were taken, I have described by a curve on Diagram 5.

DIAGRAM 5.

The *Absolute Capacity* of the thorax of 20 subjects—6 females and 14 males, in the same order as given in Diagrams 7 and 8, placed in gradation, the shortest first, and the tallest last, on the right.



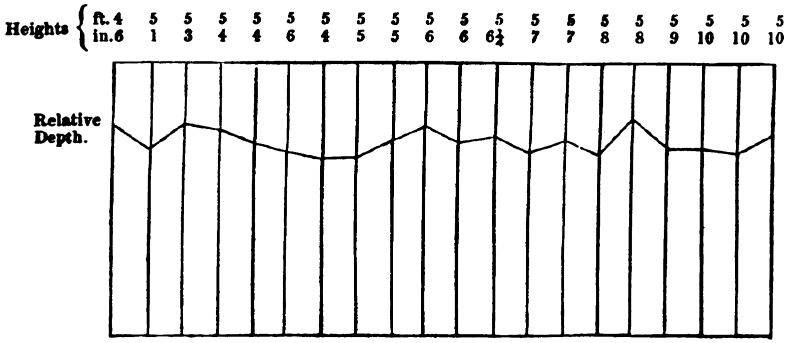
The 20 perpendicular lines are to represent the 20 cases, the shortest placed on the left hand side, and the tallest on the right, and the rest arranged in their proper gradation, with their respective heights marked at the top.

83.—The curve passing over these 20 lines represents the *absolute* capacity of the thorax, which, it will be seen, is very irregular. Whereas, had the *vital capacity* been delineated, it would have been nearly in one continuous ascent, therefore we may safely say the absolute capacity of the chest and the vital capacity do not appear as yet to have any direct relation.

84.—I have frequently been asked if the depth of the chest did not increase with the height of the individual. I find this not to be the case, as the casts will illustrate. The casts N and A (see Table L.) are taken from men of 5 feet 10 inches, and the cast Z from the shortest man, whose height was 5 feet 4 inches : the depth of the taller man's chest is about 8 inches, and that of the shortest man 10½. Therefore the depth of the thorax has nothing to do with the increasing vital capacity which so corresponds with the stature. (See Table L. columns 19, 20, 21.)

Diagram 6.

The *Relative Depth* of the thorax of the 20 cases given in Diagram 5. The heads are on the same plane with each other, and are placed in the same gradation as in Diagrams 5, 7 and 8.



On Diagram 6 I have drawn a curve, to represent the depth of the chest of these 20 cases; the heights, as in the last

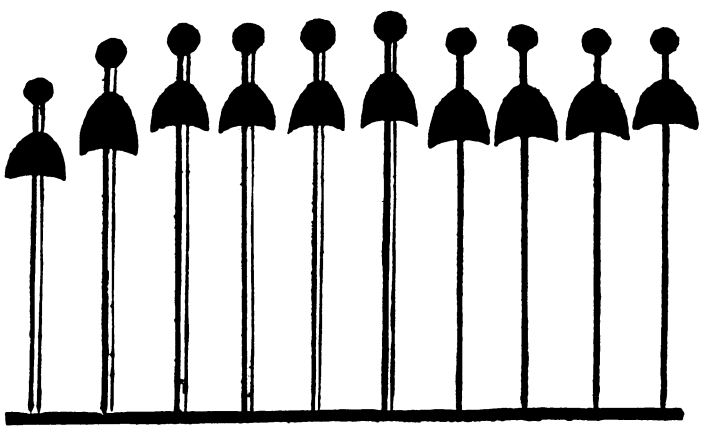
Diagram, are arranged in gradation: this curve also is nearly as irregular as the curve of the absolute capacity given in Diagram 6. There is no apparent sinking of the curve as it passes from left to right, which would be the case did the depth of the thorax increase with the height of the individual. In this Diagram the heads of the cases are all supposed to be on a plane with each other. The respective heights are given at the head of each of these Diagrams.

85.—On Diagrams 7 and 8, I have given a view of the relative *breadth* and *depth* of the thorax in these 20 cases, in relation to their stature, supposing the cases to be standing on the same plane: these also are arranged in gradation, the shortest case placed on the left hand, increasing progressively to the tallest on the right hand.

The first six are females, and the rest males. It will be observed that the relative size or section of the chests of the last five men in Diagram 8, whose height is from 5 feet 8 inches, to 5 feet 10 inches, is smaller than the six preceding men, whose heights range from 5 feet 6 inches, to 5 feet 8 inches.

DIAGRAM 7.

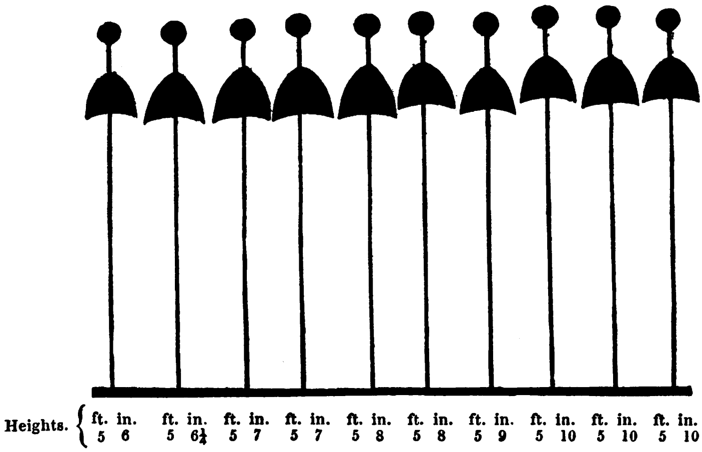
The internal depth and breadth of the thorax, in proportion to the stature, of six females and four males.



Heights	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
	4 6	5 1	5 3	5 4	5 4	5 6	5 4	5 5	5 5	5 5

DIAGRAM 8.

The same measurement as in Diagram 7, of ten males.



This is sufficient to prove, that omitting the effect of mobility, the absolute capacity itself does not correspond with the vital capacity.

DIAGRAM 9.

Sections of the chest at the base, six females and four males.

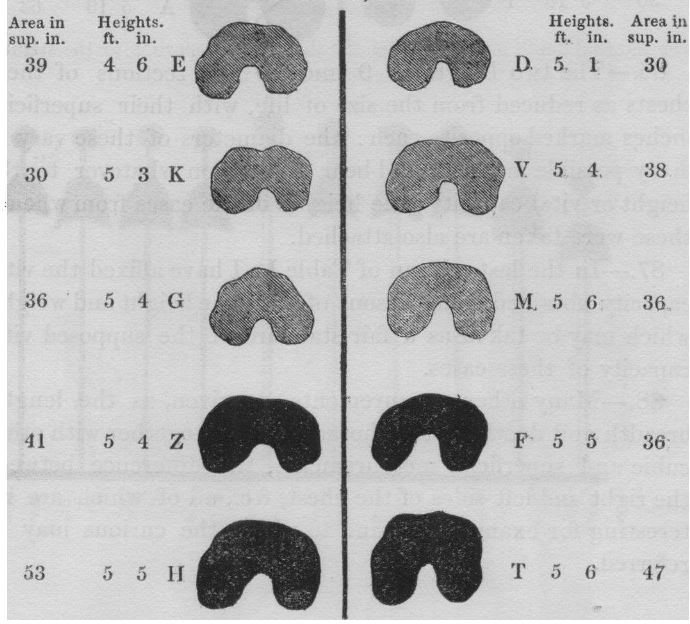
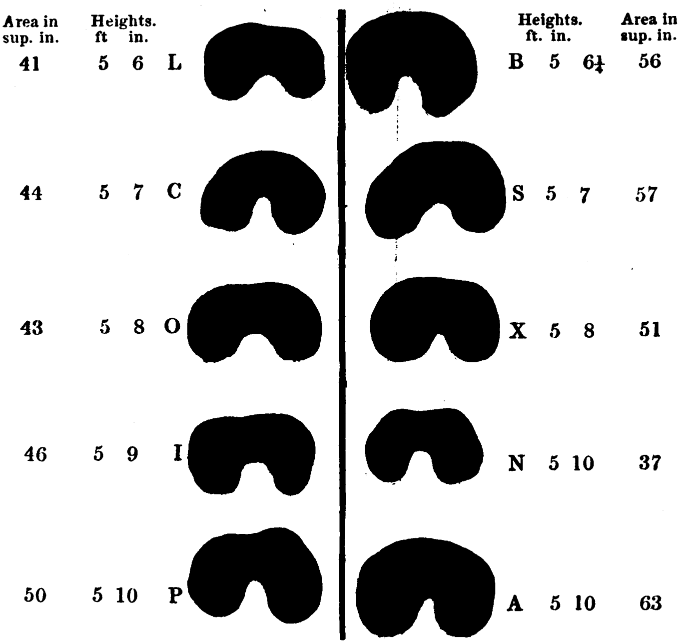


DIAGRAM 10.

Section of the base of the chest of ten males.



86.—The two Diagrams 9 and 10 are sections of these chests as reduced from the size of life, with their superficial inches marked opposite each: the diameters of these vary in every possible manner, and bear no relation whatever to the height or vital capacity; the heights of the cases from whence these were taken are also attached.

87.—In the last column of Table L. I have affixed the vital capacity obtained from persons of the same height and weight, which may be taken as a fair standard of the supposed vital capacity of these cases.

88.—Many other measurements are given, as the length, breadth and depth of the thoracic cavity, together with other cubic and superficial measurements, the difference between the right and left sides of the chest, &c., all of which are interesting for examination, and to which the curious may be referred.

89.—Having now demonstrated that there is a great difference in the vital capacity of men, and shown what it does *not* depend upon, I will proceed to consider what *is* the cause of this difference.

90.—THIRDLY.—*Of the respiratory movements, and mobility of the chest.*—I am quite at a loss to explain why height governs, or why a relation exists between the amount of air expelled, and the stature. It is well known that the difference of height is chiefly regulated by the length of the legs; I found by direct experiment upon men (between 5 and 6 feet), that whatever be their standing height, their sitting height is on an average 3 feet.

One man of 6 feet and $\frac{1}{2}$ an inch standing, sat only 2 feet $11\frac{3}{8}$ inches; while another of 5 feet 6 inches standing, sat 3 feet high; and therefore the standing height does not appear to correspond with the sitting height, or the length of the body with the length of the trunk.

91.—I will introduce a case I examined, which is here sketched.

DIAGRAM 11.

The relative height of two persons standing.

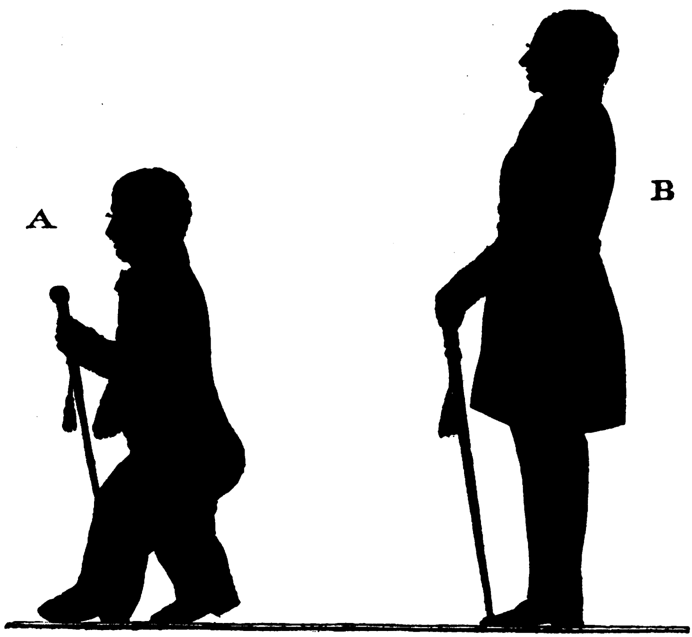


DIAGRAM 11.

The relative height of the same persons sitting.

Diagram 11 represents two men of the same age, standing and sitting. A, stood 4 feet $4\frac{1}{2}$ inches, B, 5 feet $9\frac{1}{2}$ inches. A, sat $35\frac{1}{2}$ inches, and B, $35\frac{1}{4}$ inches; the circumference of their chests were the same. The weight of A, was 7 stone $2\frac{1}{2}$ lbs., and B, 10 stone 3 lbs. The vital capacity of A, was 152, B, 236 cubic inches. Therefore, the man who sat the *shorter*, could breathe 84 cubic inches more than the man who sat rather taller. The mobility, or expanding power of the chest of the little man, was 3 inches, and that of the taller 4 inches. I have examined other cases with the same result, so that I am inclined to believe the length of the trunk of the body has little to do in regulating the vital capacity.

92.—As the mere length and breadth of the chest has little to do in affecting the vital capacity, we must look to the mobility, or range of movement of the boundaries of the thorax.

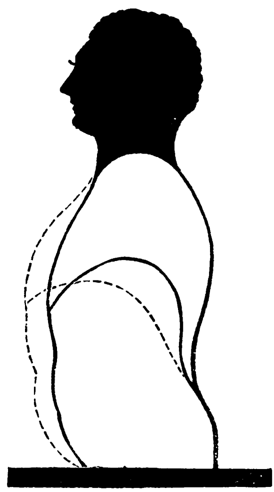
It is this mobility which I consider governs the vital capacity, to examine which I had recourse to the following experiments upon respiratory movement.

93.—The shadows of various persons were traced under a strong light, during the different stages of respiration.

94.—The present opinion of the respiratory movements, as described in physiological works, is given in Diagram 12.

Diagram 12.

Of the respiratory movements, as hitherto described.



Let the black continuous line represent the ordinary state. In deep inspiration, it is seen, the chest is chiefly enlarged by the action of the diaphragm, contracting and becoming more horizontal, assuming the position of the broken line; in this manner augmenting the cavity of the chest vertically. At the same time the sternum and abdomen advance outwards, as shown by the dotted line.

95.—This I have found *not* to be the case, although I have examined a number of persons.

96.—The following opinion appears to me more correct. Let me direct attention to Diagram 13, where I represent the tracing of a well-made young man.

DIAGRAM 13.

Respiratory movements.

Deep Inspiration, dotted line.
Ordinary state, continuous line.
Deep expiration, anterior margin of the shade.

97.—The back is supposed to be fixed, in order to throw forward the respiratory movement as much as possible; the outer black continuous line in front is the ordinary quiescent state. This line will be observed to be thicker over the abdomen than elsewhere; this represents the ordinary breathing movement. The anterior margin of this line is the boundary of the ordinary *inspiration*, and the posterior margin the limit of the ordinary *expiration*. It will be observed, this line is thin over the chest, there being over that region, in men, little or no movement in ordinary breathing.

98.—The healthy ordinary breathing movement in men is so remarkably small over the region of the chest, that I was inclined for some time to believe the movement of the ribs was altogether accidental. By a delicate instrument, I measured the costal movement in health, and found it not to exceed from two to four-tenths of a line, so that, to number the respirations, as has been done in every case (examined by the Spirometer), my hand rested (unconscious to the observer, as if feeling his pulse,) on the abdomen, it being not possible to count the breathing movements, by resting it over the region of the chest.

99.—The *ordinary breathing* movement is therefore abdominal, caused by the descent of the diaphragm pushing out the abdominal viscera.

100.—The *deep inspiratory* movement is not so, but quite the contrary; the sternum *advances* while the abdomen *recedes*; this movement is indicated by the dotted line (Diagram 13). We may conceive, by the annexed figure, an axis below the sternum, upon which this movement turns.

101.—The chief enlargement of the thoracic cavity in deep inspiration is therefore made by the ribs and *not* by the diaphragm, as is commonly believed.

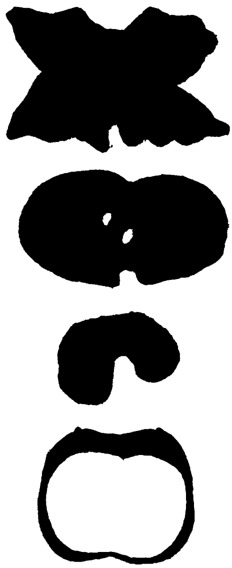
102.—So much is the abdomen drawn in, that in this deep inspiratory effort, a portion of the line of the ordinary breathing (Diagram 13) is *external* to that of the *deep* inspiration; consequently the position of the diaphragm, in deep inspiration, most probably is not flattened, or lowered, to the extent generally believed; and it appears to me a matter of great doubt whether the diaphragm in this act descends at all, as it is evident all that space between the line of ordinary breathing and deep expiration, situated below the sternum, may be considered as just so much space deducted from the abdominal cavity, which tends to induce a movement in this great effort *diametric* to that of the descent of the diaphragm.

103.—There can be no doubt that the circumference of the thorax is increased, and therefore the diaphragm must in like manner extend its borders; but I think it quite possible that this may be done without the arch being lowered.

DIAGRAM 14.

Dimensions of the diaphragm in three stages.

C, ordinary state. B, spread out. A, completely extended. E, relative difference between inspiration and expiration.



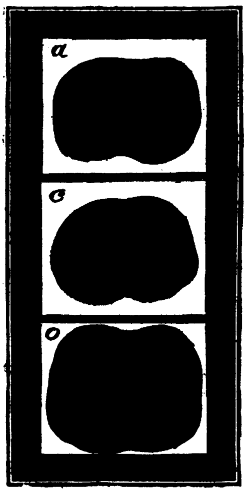
The diaphragm is a large muscle, doubled on itself, to an extent that might allow for this. I have given a section of a chest on Diagram 14, fig. C. The superficial measurement of this is 40 square inches; the figure B, next above, is the same spread out, which is extended to 110 square inches, nearly three times the area of the former figure: even in this condition the centre is quite free, and not upon the stretch, though the circumference is so. To obtain the full measurement, I slit up the sides, as represented in the figure A above, and which gives an increase of 22 square inches, making altogether 133 square inches; even then I could not spread out the entire of this arched muscle. This was the diaphragm of a man of 5 feet 6 inches, with an exceedingly small chest, 29 inches in external circumference, whose vital capacity might not be expected to exceed 188 cubic inches. I do not believe that in his extreme thoracic expansion he could increase the external circumference (and that chiefly on the anterior part) more than two inches, which would scarcely lower the arch of his diaphragm by the mere extension of its borders.

104.—These two inches of mobility of the chest must not be considered like an increase of two inches, equally, to the circumference of a regular circle. The dorsum part of the chest yields in a much less degree than the anterior portion; all that part corresponding to the angle of the ribs, situated on either side of the spine, (fig. c, Diagram 14,) cannot be expected to increase its borders like the anterior boundary of the same figure.

105.—I represent by Diagram 15 the exact outline and section over the nipples of the living chest of the same figure as given on Diagram 13, in three stages: the ordinary, the deep inspiration, and expiration.

DIAGRAM 15.

Relative difference in the three stages of respiration.



Ordinary. 80 inches.

Expiration. 74 inches.

Inspiration. 101 inches.

106.—The mobility of this chest, or difference between extreme contraction and dilatation, was 5 inches, a range by no means common.

107.—I have given these sections in three squares (Diagram 15) of the same size, that the eye may judge of the relative difference and peculiarities in the three stages of respiration. The highest figure, *a*, is the ordinary state, the superficial extent of which is 80 square inches; the centre figure, *c*, extreme contraction, or complete expiration, presenting an area of 74 square inches; and the lowest figure, *o*, that of extreme expansion, measuring 101 square inches. With this mobility the man in question could breathe out 305 cubic inches of air. From this it appears, that with a mobility of 5 inches there was a corresponding increase of 27 superficial square inches to the thoracic cavity at its base; and taking the minimum area of the chest at 74 square inches, the mobility to it, is in the relation of about 1 to 3. It is curious to observe that in the measurements of the diaphragm given in Diagram 14 there exists also a relation between the minimum area of the chest to that of the stretched out diaphragm, as 40 to 110, or about 1 to 3.

This may be accidental, but the subject appears so striking as to deserve notice.

108.—But to return to Diagram 13; having described the ordinary and deep inspiration, I will just refer to the line of extreme *expiration*, or thoracic contraction, which is indicated by the margin of the shade on the anterior portion of the body. This act appears to be a general compression of the whole anterior part. It may be observed that at the lower third of this line of deep contraction, the abdomen is as much pushed out, as the same part is when under the effect of deep inspiration: this is not so in all cases. It is difficult to say what may be the position of the diaphragm in this state of deep expiration.

109.—Diagram 16 represents the same movements in the sitting position with the back fixed; it will be seen the abdomen still recedes in the deep inspiration, posterior to that of the ordinary state. The continuous line is the ordinary state; the broken line the deep inspiration; and the margin the deep expiration.

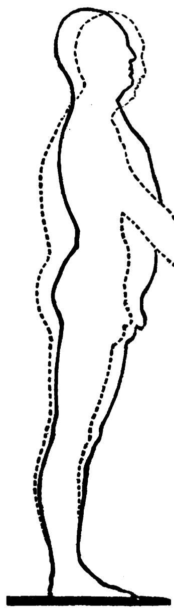
DIAGRAM 16.

Of the respiratory movements with the back fixed.

The dotted line, deep inspiration.
The continuous line, ordinary state.
The margin of the shade, deep expiration.

110.—When the back is free, as in Diagram 17, the whole body of the man, in the deep respiratory efforts, is altered from the head to below the knees; it would be difficult here to say what muscles in the body are *not* concerned in measuring the vital capacity. The continuous line is that of inspiration; and the broken line that of expiration. The head is protruded and lowered in the deep expiration; raised and thrown back in deep inspiration. The body is *lowered* or shortened in expiration. A contrary opinion has been expressed; but having examined now upwards of 1500 cases, I feel warranted in coming to this conclusion: I have seen some extreme cases of the body lowering in deep expiration one-third of its height.

Diagram 17.
Respiratory movements standing.
Dotted line, expiration.
Continuous line, inspiration.



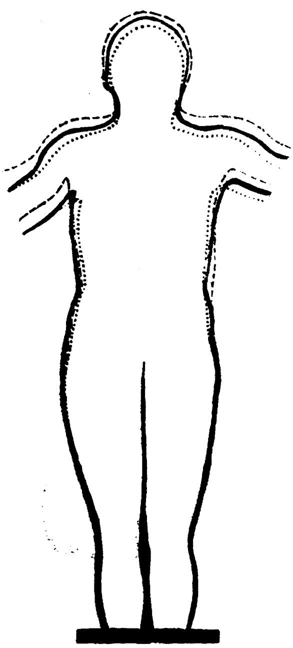
111.—I will now direct attention to the back view, under these three conditions—the ordinary, and the two extrême states of respiration.

Diagram 18 exhibits these respiratory stages; the continuous black line in the middle is the ordinary state; the upper broken line the extreme inspiration; and the lowest dotted line the deepest expiration: this strikingly exhibits how much the upper part of the chest and shoulders is raised and lowered, while the *lateral* alteration is very inconsiderable.

DIAGRAM 18.

Respiratory movements.—Male, front view.

Inspiration, broken line.
Ordinary, continuous line.
Expiration, dotted line.



112.—From these experiments on the thoracic enlargements in healthy men with the back fixed, it appears that the *Ordinary* inspiration is chiefly performed by the diaphragm, and slightly by the ribs.

Extreme inspiration by the ribs elevating and throwing forward the sternum, drawing in the abdomen, increasing the antero-posterior diameter of the chest much, and the lateral diameter but little; the descent of the diaphragm in this act is questionable.

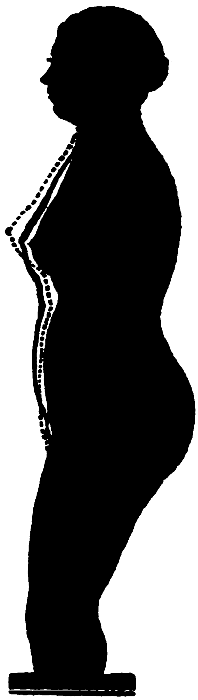
Extreme expiration, by a general compression, approximation and lowering of the ribs, and a receding or flattening of the whole anterior part of the body.

113.—*Of the respiratory movements in females.*—In Diagram 19, I give a tracing of a female figure, supposed by artists to be of perfect shape.

DIAGRAM 19.

Respiratory movements.—Female.

Inspiration, dotted line.
Ordinary, continuous line.
Expiration, anterior margin.



The three stages of respiration are delineated in the same manner as before; the extreme respiratory movements are the same as in men, as shown by the dotted line and the margin of the shade; the dotted line that of deep inspiration, and the margin of the shade that of deep expiration, but the intervening state, the ordinary movement, is not the same.

The continuous line shows this, the outer margin of which points out the ordinary inspiratory limit, and the inner margin of the same line the expiratory one.

It will be observed, the ordinary breathing movement here is chiefly over the sternum, and a more limited movement over the region of the abdomen : this is the chief peculiarity of breathing between male and female. The heaving of a woman's chest is very perceptible, even when in her full attire.

114.—I cannot account for this; I much question whether their peculiar costume is the cause of it. I examined 24 girls, between the ages of 11 and 14, who did not wear any tight dress, and I found in them this same peculiarity of ordinary breathing. So slight was their abdominal movement in ordinary breathing, that I could not number their respirations, but by placing my hand over the sternum.

It may be possible that this costal breathing is a provision against those periods when the abdomen contains the gravid uterus. (?)

115.—The front view of the female respiratory movements are given in Diagram 20, which will be seen are the same as those of men—a limited lateral enlargement, with a considerable elevation of the shoulders. The continuous line is the ordinary state, the upper and broken line deep inspiration, and the lower dotted line that of deep expiration; the body is also lowered in expiration.

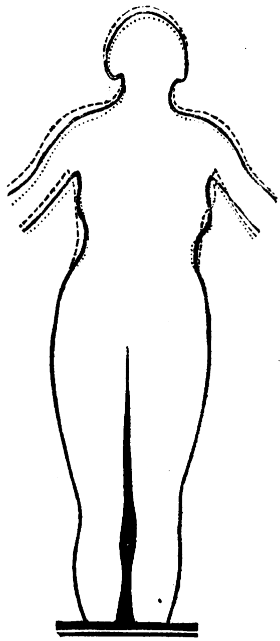
116.—I would wish to make one remark here upon observing the respiratory movements.

When examining a patient in a recumbent position, the breathing movements oftentimes appear more apparent, but this must be received with caution, because, in this state the back becomes fixed, and the previously divided motion is now all thrown forward. I believe it is in consequence of this dorsal movement being so impeded in the horizontal position, that patients labouring under dyspnœa are led to prefer the erect position, which allows of a greater mobility of the thorax than the recumbent, and hence a greater supply of air is obtained for their well-being.

DIAGRAM 20.

Respiratory movements.—Female, front view.

Inspiration, broken line.
Ordinary, continuous line.
Expiration, dotted line.



117.—Having now given a brief outline of the respiratory movements, I must recall the attention to the vital capacity. We have seen that this corresponds with the height, and not with the absolute capacity of the thorax: why is this the case? I confess myself as much at a loss to explain it as I was the first day I commenced the research. I believe the vital capacity is mathematically commensurate with the range of mobility or thoracic movement; but why the mobility increases in arithmetical progression with height, which appears is chiefly dependent on the length of the limbs, and not on the length of the trunk of the body, I am incapable of explaining. So completely is mobility, and consequently the vital capacity, affected by stature, that a man will breathe in different positions different quantities of air: thus, standing, I blow 260 cubic inches; sitting, 255; and when recumbent, (supine) 230, (prone) 220; position making a difference of 40 cubic inches.

These positions affect the mobility, and the Spirometer detects this effect more correctly than by any other system I have seen adopted.

118.—The ordinary breathing movements are so small and so much under the control of the will, that I never could gather much by instituting direct measurement from without, to determine the thoracic mobility.

I have attempted to determine the *ordinary* breathing movement by other means, well adapted for minute measurement, and even when the body was fixed behind, so as to throw all the motion forwards, yet I could not bring it to that perfection necessary for diagnosis. Nor do I think this movement can be measured from without when the whole body is free, because the mobility over the whole thorax becomes divided: we have then no fixed point to measure from, and that too, when the thoracic movement is so compound, as to partake, at the same time, of both an upward and lateral motion, *neither* of which can be estimated when measuring the advancing movement. Though I believe an instrument for this purpose has been constructed, yet I have not seen any *series* of experiments detailing what is this law of expansion, either in health or in disease, nor what relation it bears in different persons of different physical development, which tabular arrangement I would rather examine before I can believe otherwise.

119.—Fourthly. *Inspiratory and expiratory muscular power.*—Various methods have been adopted by observers to measure the muscular power of man.

Whenever the muscular power to be measured is determined by lifting, pushing, drawing, or striking, I imagine the *weight* of the individual will interfere with the result, and modify the correctness of such conclusion.

I conceive it a very difficult subject to determine the immediate power of a man. The force which a man may exert with his arms may be very considerable, yet that man may not be what is termed a strong and healthy man. It is well known amongst prize-fighters, that men strike with very different power. I examined a small-made man of this class, who complained of never enjoying health, and always feeling weak, yet the blow from this man's arm was likened by his class, "*unto the kick of a horse*;" and I have examined muscular-looking men who were evidently weak men in constitution; and others will perform feats of great strength, and yet look by no means strong.

120.—I consider power in man of two kinds; one, involuntary and present in a dormânt or latent state, but which will supply an individual as he needs it, under hardships and fatigue; the other is suddenly brought forth at the command of the will in a remarkable degree, as in performing feats of great strength, but which will not support him under long and continued hardships.

What this is dependent upon I am unable to say. I was, however, desirous of making an attempt to measure this voluntary power. With a view of further testing the health of individuals, I constructed an instrument for this purpose, which the Fellows have had an opportunity of examining.

121.—The resistance here afforded to measure the true respiratory power is a column of mercury.

The dial plate of the instrument in question is divided, to mark the inches and tenths of mercury so lifted; the communication is made by a peculiar adaptation to the nostril, that the true *respiratory muscles* only may be tested: were it by the mouth, the muscular act of smoking, or suction by the tongue, would interfere and render the observation useless.*

* "A much greater force is required, in order to produce a blast of a given intensity with a large pair of bellows, than with a smaller pair; and, for the same reason, it is much easier to a glassblower, when he uses a

Dr. Hales first mentioned this method of examination. He remarks,* "A man by a peculiar action of his mouth and tongue may suck mercury 22 inches, and some men 27 or 28 high; yet I have found by experience, that by the bare inspiring action of the diaphragm and dilating thorax, I could scarcely raise the mercury 2 inches." Had Hales examined more cases, he would have found that 2 inches was *below* the ordinary power.

122.—Two efforts are measured by this instrument, the extreme inspiratory and expiratory powers. One part of the dial is marked 0, from whence the two forces are calculated; certain words are marked on the plate, their position having been determined by 1500 experiments; the words and figures, on the left side, are the figures for *inspiratory* power, on the right, those for *expiratory* power, as follows:—

Power of inspiratory muscles.		Power of expiratory muscles.
Inches.		Inches.
1·5	Weak	2·0
2·0	Ordinary	2·5
2·5	Strong	3·5
3·5	Very strong . . .	4·5
4·5	Remarkable . . .	5·8
5·5	Very remarkable . .	7·0
6·0	Extraordinary . . .	8·5
7·0	Very extraordinary .	10·0

blowpipe, to employ the muscles of his mouth and lips than those of his chest, although these are much more powerful. If we estimate the section of the chest at a square foot, it will require a force of 70 lbs. to raise a column of mercury an inch high, by means of the muscles of respiration, but the section of the mouth is scarcely more than 8 or 9 square inches, and a pressure of the same intensity may here be produced by a force of about 4 lbs."—Young's Lect. Nat. Phil. 8vo, 1845, p. 200.

* Stat. vol. i. p. 267.

It will be observed that the figures on each side of the same word differ in their value, the expiratory side ranging about one-third higher, because the power *manifested* (I do *not* mean power exerted) by these muscular efforts varies in this relation. Thus, a man capable of elevating by his inspiratory muscles 3·5 inches of mercury, may be expected to raise by his expiratory muscles 4·5 inches: the explanation to this will be given in the next head under elasticity, &c. Haller, in his First Lines of Physiology (p. 123), in speaking of this violent effort, says, "By this force, leaden bullets, weighing above a drachm, may be blown to the distance of 363 feet, which force is equal to a third part of the pressure of the atmosphere."

123.—With the instrument in question I have compared these efforts in several classes, and ventured thus to estimate the health of the men employed in different trades, which will be seen to manifest a remarkable difference. The following is a Table of the principal cases.

Letters of reference to the different classes of men given in the next Table.

A.—Seamen.
B.—Firemen.
C.—Metropolitan police.
D.—Thames police.
E.—Mixed class.
F.—Grenadier Guards.
G.—Pugilists.
H.—Draymen.
I.—Horse Guards.
K.—Paupers.
L.—Compositors.
M.—Pressmen.
N.—Mean of Printers.
O.—Diseased.
P.—Gentlemen.
Q.—Mean of the four healthiest classes.
R.—Mean of the whole thirteen classes, except the diseased.

M.—Table of the Inspiratory and Expiratory Muscles of Respiration, in relation to Height.

CLASS.	0 to 5 ft.			5 0 to 5 1			5 1 to 5 2			5 2 to 5 3			5 3 to 5 4		
	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.
A.	3·17	3·44	5	2·20	2·60	1	2·03	3·48	7	2·40	3·74	1	2·48	3·89	9
B.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
C.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
D.	2·55	3·28	1	...	...	...	...	...	...	...	...	...	2·70	4·26	6
E.	3·00	3·74	1	2·00	3·36	1	2·52	3·25	5	2·31	3·15	5	1·85	2·69	17
F.	...	...	...	...	...	...	...	...	...	4·50	5·36	1	...	...	...
G.	...	...	...	...	...	...	3·80	4·75	1	2·40	2·41	2	3·50	3·74	1
H.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
I.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
K.	1·79	2·45	7	1·46	1·93	3	2·52	2·96	9	2·08	3·30	10	2·30	3·38	21
L.	...	...	...	...	...	...	2·32	2·96	3	1·65	2·52	1	2·13	3·23	5
M.	...	...	...	2·20	5·00	1	...	...	...	3·35	4·20	1	...	...	...
N.	...	...	...	2·20	5·00	1	2·32	2·96	3	2·50	3·36	2	2·13	3·23	5
O.	0·82	1·37	5	1·30	3·00	1	1·16	2·14	4	1·00	1·81	4	1·34	2·30	...
P.	...	...	...	...	...	...	1·50	2·80	1	2·55	3·00	1	1·77	2·92	6
Q.	2·55	3·28	1	...	...	...	...	...	...	...	...	...	2·70	4·32	8
R.	2·42	2·95	14	1·80	2·79	6	2·41	3·19	25	2·33	3·36	21	2·21	3·32	67

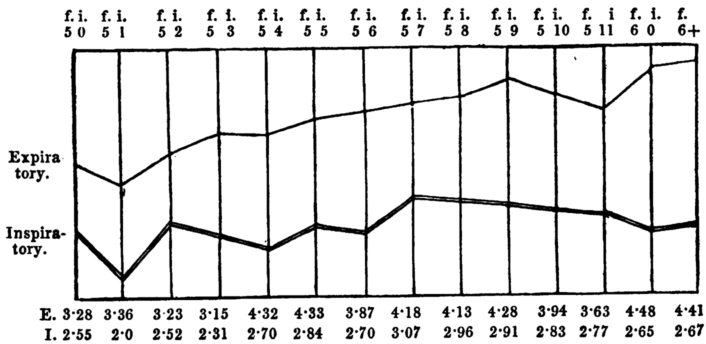
CLASS.	5 4 to 5 5			5 5 to 5 6			5 6 to 5 7			5 7 to 5 8			5 8 to 5 9		
	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Casse.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.
A.	2·68	4·23	8	2·84	4·25	15	2·63	3·56	15	2·87	4·15	14	3·11	4·19	9
B.	...	...	...	...	...	...	3·17	3·95	15	3·02	4·09	15	3·08	4·50	18
C.	...	...	...	...	...	...	3·07	4·05	4	2·89	4·07	39	2·81	4·10	46
D.	3·05	4·50	9	2·58	4·34	9	2·97	4·44	16	3·08	4·31	16	3·05	4·66	11
E.	2·30	3·05	18	2·40	3·37	16	2·31	3·38	21	2·16	3·17	27	2·46	3·50	17
F.	4·50	3·10	1	2·70	2·90	2	...	...	...	2·68	3·83	8	2·94	3·89	19
G.	3·53	5·29	3	3·86	4·75	3	4·20	6·42	2	3·65	4·61	2	3·70	4·84	1
H.	...	...	...	1·30	1·70	1	2·80	3·55	1	2·73	4·59	3	2·37	4·16	3
I.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
K.	2·17	3·30	20	1·93	3·13	19	2·45	3·33	10	1·96	2·71	8	1·87	3·33	9
L.	2·17	2·91	4	1·65	2·85	7	2·05	3·10	5	2·43	3·22	7	2·83	3·41	8
M.	2·81	4·17	3	2·04	3·27	8	2·10	2·95	3	2·62	2·58	8	1·65	2·05	1
N.	2·49	3·54	7	1·64	3·06	15	2·07	3·02	8	2·52	3·40	15	2·24	2·73	9
O.	0·74	1·00	1	1·25	1·52	9	0·79	1·70	4	1·67	1·88	7	1·32	1·78	8
P.	2·01	2·10	7	1·94	3·21	11	2·35	2·62	12	2·35	3·30	16	2·40	3·30	16
Q.	2·84	4·33	12	2·70	3·87	29	3·07	4·18	35	2·96	4·13	70	2·91	4·28	75
R.	2·48	3·51	76	2 40	3·58	110	2·65	3·65	104	2·65	3·76	163	2·75	3·94	158

CLASS.	5 9 to 5 10			5 10 to 5 11			5 11 to 6 0			6 0 to 6 +		
	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.	Insp.	Exp.	Cases.
A.	2·66	3·84	18	2·41	3·86	12	2·61	4·15	6	2·00	4·00	1
B.	2·69	3·33	5	2·40	3·74	1	3·65	6·81	2	2·10	2·80	1
C.	2·92	4·00	23	2·78	3·41	12	2·33	3·23	12	2·75	3·77	8
D.	2·54	4·27	5	2·78	4·45	3	...	...	...	...	...	...
E.	2·41	3·67	15	2·07	2·45	7	2 14	3·08	11	2·77	4·10	2
F.	2·23	3·49	18	2·56	3·76	11	1·92	3·17	12	2·46	3·82	14
G.	3·78	4·38	2	3·77	4·89	4	3·25	4·93	2	3·52	4·64	2
H.	4·50	5·43	3	3·21	4·30	6	2·02	3·13	2	3·15	5·00	1
I.	...	...	...	...	...	...	2·71	4·84	31	2·68	4·66	27
K.	2·55	3·46	1	1·47	1·67	2	1·61	3·70	4	...	...	...
L.	2·00	2·39	2	...	...	...	1·50	1·91	1	...	...	...
M.	2·95	3·93	3	2·62	3·72	2	...	...	...	...	...	...
N.	2·47	3·16	5	2·62	3·72	2	1·50	1·91	1	...	...	...
O.	0·93	1·60	3	0·88	1·59	3	0·40	2 25	1	1·65	4·02	1
P.	2·74	3·59	7	2·84	3·49	12	3·12	4·94	5	2·38	3·70	4
Q.	2·83	8·94	33	2·77	3·63	16	2·65	4·48	45	2·67	4·41	36
R.	2·65	3·79	102	2·67	3·62	72	2·51	4·11	85	2·65	4·17	58

124.—It will be observed from this Table, there is a constant difference between the inspiratory and expiratory power.

DIAGRAM 21.

Inspiratory and expiratory power in healthy cases.



On Diagram 21, I represent by curves their relative position: the upper line is the expiratory power, and the double line below the inspiratory power. The perpendicular lines are the different heights of the cases examined. The chief object of this diagram is to point out the variation between these two powers. The two rows of figures at the bottom are the inches and tenths of mercury elevated (I. for Inspiration, and E. for Expiration.

According to this, at the height of 5 feet 7 inches, and 5 feet 8 inches, the inspiratory power is greatest, and from thence the strength gradually *decreases* as the stature *increases*. The men of 5 feet 7 and 8 inches elevate a column of 3 inches of mercury; this I call a healthy power, and the men of 6 feet about 2½ inches.

125.—Many interesting comparisons may be made by referring to Table M. The "Gentlemen" will be seen to stand very low in power. A gentleman may be considered a "*tolerably good gentleman* of the ordinary stature (5 feet 8 inches) who can raise 2½ inches of mercury by the true inspiratory effort. This may account for the fact why Dr. Hales could not raise more than 2 inches of mercury by this effort.

The expiratory power I do not consider such a test of strength, or, if I may be allowed the term, the "*vis vitæ*," as the inspiratory. The expiratory muscles participate in other duties besides that of mere expiration—the vocation of the glassblower, the trumpeter, the wrestler, the jeweller (blowpipe), and the sailor, especially call these muscles into use, disturbing their natural power. They become oftentimes preternaturally strong. The inspiratory muscles are for supplying us with air, in which act they oppose only a uniform and ordinary resistance to the elasticity of the lungs, ribs, and their cartilages, and do not so conspicuously assist in the varied operations of life, and, consequently, are not subjected to any extraordinary resistance; therefore, in examining the inspiratory and expiratory powers, vocation must be considered, which, should it interfere, the difference is so remarkable as to awaken attention.

I have seen in a wrestler the expiratory power exceed nearly four times that of the natural inspiratory power, which vast preponderance was purely the effect of his favourite amusement.

The diminution of this enormous surplus power may or may not be attended with an alteration in the *vis vitæ*: the question therefore of estimating the health from the *expiratory* power alone, becomes complicated and difficult. The *inspiratory* power is not subject to such changes, it is more uniform, and may remain constant, while the other is oscillating; therefore I am inclined to look for the first intimation of debility from disease in the inspiratory effort, and not the expiratory; the expiratory muscular power may however be taken as a test of health when it exceeds the inspiratory.

126.—This instrument will correctly measure the difference of force produced by the inspiratory and expiratory efforts on the same individual; but when we compare men of different sizes, the question becomes more complicated; then the hydrostatic law of the pressure of fluids must be recollected (144; and note, p. 198).

127.—FIFTHLY. *Of the elasticity of the ribs, and estimate of the voluntary respiratory power.*—We may consider all animal power under two heads, each possessing specific properties, elasticity and muscular contractility, both of which may be so combined as to produce one common effect.

In measuring animal power, these two operations should be kept distinct, differing widely in their characteristic properties.

128.—Elasticity depends simply on re-action, and restores in a contrary direction the force which had been impressed; the effect produced is commensurate with the amount of the cause, and the re-action can never take place so long as the cause continues to be applied; but immediately that cause ceases, elasticity comes into action.

In muscular contractility the mechanical effect is infinitely greater than the mechanical cause producing it; moreover the *cause* of the force, and the *effect*, operate at the same time, and the re-action surpasses the force of the agent.

Muscular power has excited frequent attention. Borelli* has calculated that the immediate force of the biceps is equivalent to about 300 lbs, and that of the muscles which raise the lower jaw above 500 in man, but in beasts of prey far greater. Young says,† "It is obvious that in muscles of the same kind, the strength must be as the number of fibres, or as the extent of the surface which would be formed by cutting the muscles across; and it is not improbable that the contractile force of the muscles of a healthy man is equivalent to about 500 lbs for every square inch of their section."

129.—A calculation of the elastic power of the body has apparently drawn little attention, and yet it performs a most important and powerful part in the respiratory function, not as a source of power, nor originator of motion, but as a restorer in a contrary direction to the force impressed—an antagonizer to muscular power: thus a power is obtained in the body, and that to an enormous extent, independently of any direct drain upon vital energy.

* De Motu Animalium, 4to, 1710. Ludg. Bat. p. 30 *et seq.*

† Lect. on Nat. Phil. London, 1845, p. 99.

130.—There is probably no function in the body that employs these two forces so powerfully as that of respiration, every inspiration being an act of muscular power, and every expiration that of muscular and elastic power; by the former in the action of the diaphragm and thoracic muscles, and by the latter in that of certain muscles, the elasticity of the ribs and their cartilages, together with the lungs.

131.—The broad difference manifested in my experiments upon the respiratory powers between inspiration and expiration (Table M. 125, 126), was sufficiently marked to induce me to examine into the elasticity of the ribs as the cause of difference. We have seen that the expiratory power is on an average one-third stronger than the inspiratory power, or that it manifests itself as such on the instrument for measuring power.

132.—I believe that this third of increasing difference is chiefly due to the elasticity of the ribs, and not due so directly to muscular force. To determine this point I had an opportunity of examining, after death, two cases under the most favourable circumstances for this inquiry, viz. before the body had lost one degree of its natural temperature.

133.—One was a young man 22 years of age. Weight 9½ st., height 5 ft. 10 in.; his vital capacity was 235 cubic inches at 60°. The *absolute* capacity of his chest was 248 cubic inches; the internal superficial measurement 256 inches; circumference of this chest, alive, over the nipples, in the ordinary state 33 inches, dead 30½ inches. When alive he breathed 235 cubic inches: after death I forced into his lungs certain quantities of air *within* this limit, when the temperature of his body was at 97°, the remains of his own animal heat. It is clear that any force resisting this introduction of air must have been principally due to the elasticity of the ribs and their cartilages, and the lungs, and not to any voluntary muscular power. It will be seen the difference of the size of the chest between life and death was 2½ inches, therefore death was attended by an expulsion of the reserve air, or a complete expiration: this reserve air I calculated to be 70 cubic inches.

134.—By an arrangement I could force in any quantity of air, and measure the power with which it returned, by the elevation of a column of mercury : the following was the result :—

	cub. in.			
Forced in	70	resisting elasticity	1·20	of an inch of mercury.
Ditto	+20	ditto	1·25	ditto
Ditto	+70	ditto	2·50	ditto

The total quantity of air forced in was 160 cubic inches; beyond this I could not proceed, the lungs having burst on introducing the first portion. I then found it impossible to prevent air escaping, owing to the power of elasticity, and, that, *not* of the lungs, but of the ribs. I repeated this experiment three times, with the same result, the chest always returning with very considerable force to the original position. The total quantity of air forced into the chest will be observed was 75 cubic inches *less* than the quantity he could draw in and expel when alive, which was 235 cubic inches.

135.—The second case was a man of 5 feet 8 inches; weight 10 st. 10 lbs; age 21; vital capacity 200 cubic inches, *absolute* capacity 245 cubic inches, superficial inches of the entire cavity of the chest 256 square inches; circumference of the chest, alive 33 inches, dead 34½. Temperature of body when examined 97° F. Temperature of the air forced into his lungs 63° F. In this man the following was the elastic power of the ribs.

	cub. in.			
Forced in	70	resisting elasticity	1·00	inch of mercury.
Ditto	+20	ditto	1·50	ditto
Ditto	+90	ditto	3·25	ditto
Ditto	+20	ditto	4·50	ditto

136.—The first 90 cubic inches introduced ruptured the lungs, but I continued forcing in the subsequent portions of air, at the same time preventing any escape, so that this may be considered as the elastic power of the ribs and their cartilaginous and ligamentous attachments. From this experiment it will be seen, that this man when alive breathed 200 cubic inches into the Spirometer, and when dead the same quantity was resisted by an elastic power of 4½ inches of mercury; therefore the voluntary effort required to breathe out 200 cubic inches when alive, must have demanded a muscular power equal to resisting an elastic force commensurate to 4½ inches of mercury, upon every square inch of his chest which was moved or expanded by muscle. This man was muscular and well developed; the other was thin, tall, and not muscular: the two experiments run very nearly the same. I shall place them in juxtaposition.

N.—Table of Costal Elastic Power.

H.		C.	
Cubic inches.	Elastic resistance.	Cubic inches.	Elastic resistance.
	Inches of mercury.		Inches of mercury.
70	1·20	70	1·00
+20	1·25	+20	1·50
+70	2·50	+90	3·25
0	0	+20	4·50

137.—The geometrical increase of elastic resistance I must leave to the mathematician, and here only venture a remark upon the muscular power exerted to overcome the elastic power. I may also mention, I could not determine any question touching the elasticity of the lungs, as in each case these organs were ruptured by the force applied from within to overcome the elastic power of the ribs; the mean quantity of residual air I exhausted was only 40 cubic inches. There are here also some valuable points to be gained respecting the propriety of insufflation, but this must form the subject of a separate paper.

138.—According to these two last experiments, what shall we say was the muscular power exerted in inspiration during life? For convenience I will take the case of C. in the last Table. In the four stages of inspiration, the elastic resistance was as 1, 1·5, 3·25, and 4·5 inches of mercury. If these inspiratory efforts were the result of equal muscular force, equally distributed over the whole thorax, the muscular inspiratory power would be easy of calculation. Taking chest C. at 206 superficial inches, it would appear as follows :—

O.—Table of Inspiratory Muscular Power, if equally applied, resisting Costal Elastic Power.

Air forced into chest.	Inches of mercury elevated.	Costal elastic power to be overcome in the sq. in. in ounces.	Total muscular power merely resisting the elastic costal power. in lbs.
cub. in. 70	1·00	7·8	104·4
+ 20	1·50	11·7	150·6
+ 90	3·25	25·3	326·3
+ 20	4 50	35·1	451·9

139.—Under this supposition the man when alive exerted a muscular power in making the deepest inspiration equal to the resistance of 451·9 pounds avoirdupois. This power is very considerable. But this state of things does not precisely exist, because the distribution of muscular fibre and mobility is not equally applied in expanding the chest. Let us look at fig. E, Diagram 14, which is taken from Diagram 13; the portion marked black is the range of mobility between extreme expiration and inspiration. This man could expel upwards of 300 cubic inches of air; and no doubt under the same consideration as the last estimate, the *elastic* resistance may be calculated at nearly 1000 lbs.

140.—The next inquiry is, how far is the distribution of the inspiratory muscular fibre and movement removed from that of being equal in its power and latitude of motion at every point of the chest? This is difficult to answer. In fig. E, p. 188, I have supposed the bodies of the vertebræ to be fixed (but it is most probable no part of the chest is actually fixed): from such figure it appears the lateral movement is little, the anterior movement greatest, and the dorsal the least. It is probable this general statement corresponds to every part of the thorax, and may be safely used.

141.—But what shall be said for a more definite opinion? Shall I venture to allow, in ordinary efforts, one-third of the surface of the chest to be supposed passive, and the other two-thirds equally active in mobility and power? i. e. two-thirds lifted by the inspiratory muscles, and one-third left dormant? I think I am perfectly safe in offering this somewhat rude opinion, as very considerably *within* the mark; let us see what would be the muscular power exerted in making a deep inspiration, in the case of C. Under these circumstances, the elastic resistance may be stated as 301 lbs., or 23 ounces on the inch: this force, at *least*, was to be overcome by muscular power in the act of a deep inspiration, a resistance we scarcely feel. Doubtless when a man dies, the costal elastic force ceases to be in action, the ribs collapse, and residual air only is left in the body; but at every period during life they are antagonised by muscular power, which power must vary with the different quantities of air we draw into the lungs. According to the two cases here experimented upon, one died in a state of perfect expiration, the other not so, but more under a state of full inspiration. This does not militate against our last assertion; the peculiar circumstances of death in this case fully explain this apparent anomaly. From the first case, allowing, as before, one-third of the surface of the chest as not acted upon by muscular power, it may be stated that the different portions of breathing air require the following (muscular) power, merely to antagonise the elastic power of the ribs :—

P.—Table of the Inspiratory Muscular Power exerted to draw Air into the Lungs (corrected).

Different stages of inspiration.		Elastic resistance in ounces on the square inch.	Total lbs. on the chest, or total elastic costal resistance to the inspiratory muscles.
From 1st case .	Reserve air . .	5·6	69·6
	Breathing air . .	7·8	104·4
From 2nd case .	Vital capacity. .	23·0	301·0

142.—This power I think may be *safely* reckoned as *within* the mark, for here the elasticity of the lungs is entirely omitted, which no doubt is considerable, but which I have not had an opportunity of estimating.

These cases were small men, with narrow chests, and one of them (the former) slender made, so that they may be taken probably as minimum cases of elastic power. Thus we see the resistance to the *ordinary breathing* force, *independently* of the elastic power of the lungs, was equal to lifting more than 100 lbs. at every ordinary inspiration, and that 18 or 20 times a minute, supposing the "*breathing air*" 20 cubic inches!

143.—*Of the voluntary power of the respiratory muscles.*—The last remarks have been on muscular power, as exerted to overcome costal elastic power, but the respiratory muscles are capable at will of exerting a still greater effort; this I have already shown under the 4th division, on inspiratory and expiratory power (Table M., p. 201).

The calculation of this effort I can only present as an approximation to the truth, but, I am sure, it is a power very extraordinary.

144.—Suppose a man to lift by his inspiratory muscles 3 inches of mercury, what muscular effort has he used? The mere quantity of fluid lifted may be very inconsiderable, (and as such I have found men wonder they could not elevate more,) but not so the power exerted, when we recollect that hydrostatic law, which Mr. Bramah adopted to the construction of a very convenient press. To apply this law here, the diaphragm alone must act under such an effort, with a force equal to the weight of a column of mercury, 3 inches in height, and whose base is commensurate to the area of the diaphragm.* The area of the base of one of the chests now before the Society, is 57 square inches, therefore had this man raised 3 inches of mercury by his inspiratory muscles, his diaphragm alone in this act must have opposed a resistance equal to more than 23 oz. on every inch of that muscle, and a total weight of more than 83 lbs. Moreover the sides of his chest would resist a pressure from the atmosphere equal to the

* See note, page 198.

weight of a covering of mercury, 3 inches in thickness, or more than 23 oz. on every inch surface, which if we take at 318 square inches, the chest will be found resisting a pressure of 731. lbs, and allowing the elastic resistance of the ribs as 1½ inch of mercury, this will bring the weight resisted by the chest as follows :—

Diaphragm	'83 lbs.
Walls of the chest	731
Elastic force	232
Total . .	1046

145.—In round numbers it may be said that the parietes of the thorax resisted 1000 lbs. of atmospheric pressure, and that not counterbalanced,—to say nothing of the elastic power of the lungs, which co-operated with this pressure.

I would not venture at present to state exactly the distribution of muscular fibre over the thorax, which is called into action when resisting this 1046 lbs., but I think I am safe in stating that nine-tenths of the thoracic surface conspire to this act.

What is here said of the muscular part of the chest resisting such a force, must not be confounded with a former statement (141), of " two-thirds being *lifted* by the inspiratory muscles, and one-third left dormant," under a force equal to 301 lbs. In this case the 301 lbs. are *lifted,* in the other, nine-tenths of 1046 lbs. are said to be *resisted.*

The glass receiver of an air-pump may *resist* 15 lbs. on the square inch, yet it may be said to *lift* nothing. This question of the thoracic muscular force and resistance, and muscular distribution, is rendered complicate by the presence of so much osseous matter entering into the composition of the chest, which can scarcely be considered to act the same as muscle.

146.—Now it will be seen why the expiratory power is manifested as so much greater than the inspiratory; the elasticity of the ribs is quite sufficient to account for this, and may be proved in another way. Try the expiratory power (by such an instrument as the one before the Society) with the chest empty, observe the utmost expiratory power, probably equal to 1½ inch of mercury, then inspire deeply, filling the chest; now test the expiratory power, and instead of 1½ inch, it will probably be 5 inches.

This difference, I am inclined to think, is due to two causes:—

1st. The elasticity of the ribs, after deep *inspiration, most* powerfully assists in the *expiratory* act; but when the ribs are more collapsed, their elasticity, though co-operating, is of necessity considerably diminished.

2ndly. The chest, when distended with air, presents points of attachment for muscular traction to a greater mechanical advantage than when it is empty.

This experiment proves the elastic force of the ribs as one source of power in *expiration,* whereas this power opposes the *inspiratory* act (to say nothing of the co-operating power derived from the elasticity of the lungs); therefore, the one-third difference prevailing through Table M., between the inspiratory and expiratory power, is not all due to the actual voluntary power being greater in expiration than inspiration, but due to the interference of elasticity. In other words, the vital energy demanded to produce these two forces, inspiration and expiration, is not equally manifested by any dynamic instrument. It is true, two powers are measured, but we cannot refer these powers to two classes of muscles, when a third and involuntary power co-operates with one class and not with the other, until the influence and distribution of that involuntary power be correctly known. All the power manifested in expiration is not muscular, whereas all the power manifested in inspiration is muscular. Nevertheless, I am inclined to believe that the expiratory muscular power is greater than the inspiratory.

147.—The most extraordinary respiratory power I have known, was the case of a Chatham recruit. The experiment was made, and frequently repeated, by my friend

Dr. Andrew Smith, on whose accuracy I place implicit confidence.

The man's age was 18, height 5 feet 6 inches, weight 10 stone 5 pounds, circumference of his chest 35 inches, vital capacity 230; and his inspiratory power was 7 inches, and his expiratory 9 inches! In fact, he reached the limit of the instrument, and there is reason to believe he could have done more than this. At what shall this man's thoracic muscular power be estimated? According to the last calculation, upwards of 2200 lbs., or nearly 2 tons, must have been resisted. I do not say directly lifted, but resisted *without any* counterbalancing pressure, and two-thirds of this, at least, directly *lifted* by his inspiratory muscles.

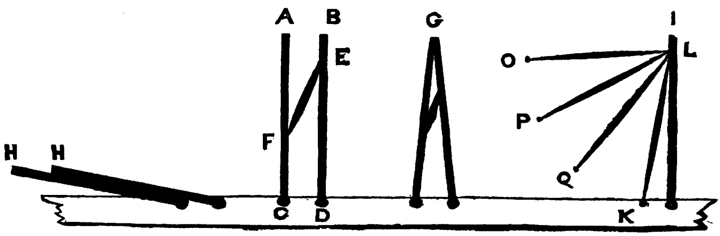
148. — SIXTHLY. *The effect of decussating, diametric, and oblique power, in reference to the function of the intercostal muscles.*

The true function of the intercostal muscles appears still to be involved in obscurity, as no single explanation is admitted without disputation, while laws which are known, admit but of one explanation.

It is not my intention here to enter into the anatomy of the thoracic muscles, nor their specific movements; these must form the subject of a separate communication.

I will but venture to make known what I have found to exist respecting the influence of oblique power directed on parallel bars, and of which effect I have not, according to my understanding, been able to find any account, either in any of the physiological or other works I have consulted.

DIAGRAM 22.
Effect of oblique power on parallel bars.



149.—Let A B, (Diagram 22,) represent two parallel bars, fixed on an axis at C D, which allows of their free rotation, as radii from a centre; imagine a muscle placed obliquely in the direction of E F, let this contract, and what is its effect upon these two bars A B? The answer made to this is, that it will only cause the bars to approximate each other as at G. This is not the case; they will assume the position of the bars H H. Change the direction of the muscle E F, to a contrary course, and the effect will be diametrical to that of H H, drawing the bars to the right side. This cannot admit of disputation.

150.—Let I represent one of the same radiating bars, and K the point or axis where the other bar might be fixed; let L O represent a contracting muscle, the effect of which is to draw the bar *towards the fixed* point O; but instead of making O the fixed point, let P be considered the fixed point, and the effect will be the same, and the same again if Q be the fixed point; but instead of Q, let it be placed at the point K, the axis where the other parallel bar might be placed, and the effect will be still the same, drawing the bar I towards the fixed axis K. But it is not necessary that the muscle L K must contract in its entire extent to draw the bar I towards the point K, two-thirds or more of this long muscle or contracting substance might be made of any non-elastic substance—as wire, wood, or bone, which will still serve to *communicate* the point L to the fixed axis K. Consequently the bars A B are drawn into the position H H, by the muscle E F taking its fixed axis *at* C *and not at* F, to draw upon the bar B at the point E.

151.—Therefore the effect of an intercostal muscle is to draw its rib towards the fixed axis, which is either the head of the rib next above, or to the sternum, according to the direction of the muscular fibre towards that axis.

152.—To determine the action of the intercostal muscles, we have but by common dissection to find the fixed axis. The external intercostal bearing a direction obliquely downwards and forwards, it is evident their action must be to draw each rib *upwards*, every fibre taking its fixed axis from the head of the rib next above, *therefore every external intercostal muscular lamella* CAN *raise a rib, independently of the lamella next above it.* The eleven external intercostal lamellæ on each side, have, therefore, eleven fixed points, from which they can each *independently* lift a rib; but were all the external intercostal lamellæ to act *equally*, there would be a general rolling motion, over the head of each rib, and the fixed axis then would be the first rib; in this case the head of each rib may be considered as pushed, and not pulled upon in this general rolling motion. This is supposing a costal motion, which I believe rarely exists. The ribs act independently, i. e., costal respiration may be maintained by any pair of ribs. We possess a power of pumping in air with any limited part of the thorax, just as the uterus has a power of partially contracting into the hour-glass shape, therefore I still am disposed to consider the head of each rib as a fixed axis, and that each lamella of intercostal muscle acts *independently* of the lamella next above it.

153.—Though the course of the internal intercostal muscles is in a contrary direction, yet it may be possible that they also are elevators of the ribs in conjunction with the external intercostal muscles, because, though they are diametric in their direction, their fixed point also appears diametric, being to that of the sternum instead of the vertebræ. This requires more consideration, therefore I would wish to defer it at present.

154.—This effect of oblique power as here stated, militates against the opinion that the first rib must of necessity become fixed, for the others to pull upon. Were this the case, what would become of the costal movement when a rib was fractured? All the ribs below the fractured one (granting that the fracture cut off the communication) would be without a fixed point for their intercostal muscles; but allowing every rib to present a fixed axis, costal respiration can be maintained with ease under such circumstances (151).

155.—I have also observed, that in *inspiration* the ribs *diverge* from each other, and in expiration they *converge* towards each other—their movement somewhat resembles the action of a lady's fan. Moreover, the ribs may *diverge* from the *direct effect* of intercostal muscular *contraction*, by reason of their gliding movement over each other—a movement common to two or more radii relatively fixed by their end upon a line with each other, just as the bars H H (Diagram 22) must diverge in assuming the position of the bars A B C D, in which act an intercostal muscle must shorten.

156.—SEVENTHLY. *General and practical deductions, in reference to detecting disease by the Spirometer, and the method of its application.*—As the value of every research is in proportion to its usefulness, I hope this subject will be submitted to a careful and impartial examination by others, so that its intrinsic worth may be tested.

It is not easy to determine how extensively the great function of respiration is connected with our bodily health. Boerhaave * appears to have looked upon respiration as a subject of vast importance; he went so far as to say (and I think not without justice), "That scarcely any particle remained in the body which was not more or less concerned in the business of respiration;" "and he subjoins with great justice (says Morgagni†), that the great number of the organs which concur to the performance of this action, any one of which being injured, disturbs the whole function, and creates the highest difficulty in diseases." It is evident Morgagni was impressed with the truth of this opinion, for he devotes many chapters or letters to the diseases which affect respiration.

157.—I shall briefly state my own experience of the Spirometer as a means of diagnosis, that others may have an opportunity of confirming or refuting my conclusions, and shall assign the reasons why I believe its application useful.

* Prelect. ad Inst. 601.

† Morgagni on Seats and Causes of Disease, Transl. by Alexander, 4to, Lond. 1796, vol. i. p. 357.

158.—It will be seen that an investigation has been made upon upwards of 2000 persons, the great bulk of whom are considered as belonging to the healthy classes of society, which will necessarily place us in a position for judging between the healthy and diseased.

159.—The range of observations made upon the diseased, is very limited compared with those upon the healthy; but this, if any thing, makes the test stronger, as one disturbing case, amongst few, is more prominent than one amongst many.

160.—These observations are of two kinds, one measuring *quantity*, and the other *power*: the quantity of air breathed, and the power of the respiratory act—both extreme efforts.

161.—The measuring of quantity or vital capacity is most useful in private practice, the measuring of the respiratory power in selecting men for the public service. To determine the presence of disease and the presence of health requires a distinct series of observations, the duties in civil and military life being very different.

162.—It has been seen (42) that healthy men have a vital capacity which differs according to certain physical variations, while those men physically the same have the same vital capacity.

163.—A difference of vital capacity in men of the same physical development can only be accounted for as the effect of some cause, and that, most probably, disease.

The following Table shows the difference produced by phthisis pulmonalis:—

164.—Q.—Table of the Comparison of Healthy and Diseased Cases.

Phthisis Pulmonalis.			
Early Stage.		Advanced Stage.	
Vital Capacity. Diseased.	Vital Capacity. Healthy.	Vital Capacity. Diseased.	Vital Capacity. Healthy.
Cubic inches.	Cubic inches.	Cubic inches.	Cubic inches.
113	220	59	135
115	173	89	224
105	173	108	254
130	204	72	135
128	220	80	229
120	229	75	254
100	193	34	246
140	246	171	270
100	204	60	237
110	220		
136	229		
135	204		
192	230		
225	300		
145	220		
200	240		
185	230		
218	240		
129	220		
344	434		
220	260		
196	254		

165.—These cases were not from my own diagnosis, but individuals sent to me by others, well skilled in auscultation. One class is said to be in the early stage of that disease, and the other in the advanced stage; consequently there will be seen two ranges of figures under each division, one higher than another. The figures under the *early stage*, on the left, mark the vital capacity of the men as they *were*; those opposite, the vital capacity, as they would have been if healthy; the same arrangement is maintained under the words *advanced stage*.

166.—The healthy range, with the exception of the highest, is taken from men of the same physical development, being the mean of some hundreds of observations, the standard of health. The highest case is Freeman, the American, as compared with himself at different times.

167.—It will be seen by this Table, under *early stage,* the men measured a mean vital capacity of 149 cubic inches, instead of 224, an average difference of 75 cubic inches; and, in the more advanced stage, the mean of the diseased 83, instead of 220 cubic inches, a difference of 137. It will be observed there is one case, in the advanced stage, where a man could only breathe 34, instead of 246 cubic inches, a deficiency of 212 cubic inches. The most interesting case is that of Freeman, the "American Giant."

168.—This man came over to England in 1842, and, in the November of that year, trained for a prize-fight; I examined him immediately before his *professional engagement,* when he might be considered in the "best condition." His powers were as follows:—Vital capacity, 434 cubic inches; height, 6 ft. 11¼ in.; weight, 19 st. 5 lb.; circumference of his chest, 47 inches; inspiratory power, 5·0 inches; expiratory power, 6·5 inches. In November, 1844, exactly two years afterwards, he came to town in ill-health. I then examined him in the same way as before, twenty times at various intervals, during which his vital capacity varied from 390 down to 340, and the mean of all the observations was 344 cubic inches, a decrease of 90, or more than 20 per cent.; his respiratory power had decreased one-fifth, and his weight 2 stone. At this time I took him to two physicians well skilled in auscultation, and they both affirmed that they could *not detect* any organic disease. After January 1845, I lost sight of Freeman, and, in the October following, I was kindly favoured with the following account of him from Mr. Paul, Surgeon to the County Hospital, Winchester.

169.—"Freeman was admitted into this hospital on the 8th of October, in an extreme state of debility and exhaustion; he was reduced almost to a skeleton, complained of cough, and was expectorating pus in large quantities. Percussion on the anterior part of the chest *under the clavicles*, gave, on the right side, a very dull sound; on the left one, much clearer, but still I think less resonant than natural; I made but one attempt at auscultation, but could come to no conclusion, from a rather singular reason,—the ribs were so large, the intercostal spaces so wide, and so sunk in from the extreme state of emaciation to which Freeman was reduced, that I could not find a level space large enough to receive the end of the stethoscope; could not, in short, bring its whole surface into contact with the chest. Freeman's great debility, and the clearness of the diagnosis from other sources, prevented my repeating the attempt. Freeman, after death, measured 6 ft. 7½ in., and weighed 10 st. 1 lb. On opening the chest, the lungs on both sides were found adhering by their apices to the superior boundaries of the thorax, and studded throughout their substance with tubercles. The tubercles, on the whole, were much less numerous in the right lung than in the left; both lungs were nearly healthy at their base; the tubercular matter gradually increased in quantity towards their upper parts, and the apices of both lungs were almost completely occupied by large cavities partly filled with pus, and capable of containing two or three ounces of fluid each. The heart was remarkably small. The rest of the viscera appeared healthy."

170.—It is very remarkable to see that Freeman lost so much weight; in his prime, he never appeared stout, but strong and muscular. I have been informed, when he first came to England, his weight was 22 stone; he died 10 stone: his natural height was nearly 7 feet, and he died 6 ft. 7½ in.

171.—The Spirometer was useful to me in this case, by indicating the commencement of the disease which ultimately caused his death, and that *before* the usual means availed.

Another good illustration I may relate; a surgeon called upon me when in full practice; he looked in *perfect health*, and said he was so. I measured his vital capacity, and found it 100 cubic inches below the healthy standard; four months afterwards I heard he was ill, and that auscultation had given evidence of phthisis pulmonalis; a few months afterwards he died of that complaint. This gentleman looked so remarkably well when I first examined him, that I was led to doubt the extent of reliance to be placed upon the Spirometer, but the result entirely removed this doubt.

172.—Another gentleman, holding an elevated position under Government, manifested a great deficiency of vital capacity, and that too when performing his duties; but, within four months, his death took place, and extensive tubercular disease was found in the lungs.

Another case presented itself in one of the men (J. S.) in the Queen's Company, Grenadier Guards; his height was 6 feet 4 inches; his vital capacity only 102 instead of (at least) 300 cubic inches. This man was given to me as a healthy case, but I classed him among the diseased; and, upon inquiry, it was found that he had previously solicited to be relieved from certain physical duties. This is not the only case of a low vital capacity in that regiment.

173.—The last case I shall mention of this kind was a young man of 11 stone, and 5 feet 7 inches high, firm and muscular; his vital capacity was 47 cubic inches below the mark. Within one week of this time I had an opportunity of examining his lungs, and found the left lung at the apex studded with miliary tubercles, the whole not extending beyond a square inch, the entire remaining portion was to all appearance healthy.

174.—I have also had cases of a converse nature. A man who had gone the round of the principal hospitals, looked so ill that I selected him as a case for illustration of phthisical disease, but I found his vital capacity exceeded the healthy standard; I inquired about him eight months afterwards, and was informed that he had returned to work, and was *well*. A jeweller called upon me one day, and said he was told he had consumption, and having a large family, his mind in consequence was much depressed. I found his vital capacity exceed the natural or healthy mean: an explanation of the circumstance relieved the man's mind, and in four months he had so increased in weight and strength, that all his apprehensions were removed. I will not take up the time of the Society by relating other cases.

175.—These results are no more than might be expected; it is evident if a man breathe 200 cubic inches of air at 98, that in his lungs there must be 200 CUBIC INCHES OF SPACE FOR AIR. It is also certain, that if this man expel at another time from his chest 20 *per cent. minus* that, some *cause* must produce *this effect.* It may be in the lungs or it may not—the Spirometer being a guage in a two-fold sense, a measure for mobility as well as a measure for capacity, because a man cannot breathe without moving.

176.—The respiratory movements I have shown, extend at least over the whole trunk of the body (Diagram 17), and whatever disease attacks this portion of the frame (at least of an acute form), *must* affect this mobility, which can be simply and correctly measured by this instrument. A full meal even will make a difference in the vital capacity, and that inversely commensurate with the capacity of the stomach. I have found a dinner diminish the vital capacity to the extent of 12 and even 20 cubic inches.

177.—In the act of making a deep expiration, we must, of necessity, induce a deep inspiration, during which efforts the whole abdominal viscera have, to an extent hitherto little noticed, been disturbed, and if organic disease be present, the abdominal mobility will be lessened; the converse, also, will hold good—but collateral observations, with the scales, pulse, and general appearance, will show whether the decrease be the result of abdominal or thoracic disease.

178.—The mobility of an ordinary man's chest is about 3 inches; it may be determined by simply passing round the thorax a tape measure over the region of the nipples, then requesting him to inspire and expire deeply; the difference between these two acts will be the "*mobility.*" This of itself is an observation which will be found useful, and I can affirm it will be found no less valuable than simple, because it *may* be possible that the mobility is tolerably good even above 3 inches, and the vital capacity bad; in this case, it is probable, the lungs are not sufficiently permeable to air.

179.—The discovery of the seat of disease demands the consideration of a number of circumstances, and every observation forms a link in the chain of evidence leading one way or another; and that observation which can be measured, and is capable of definite expression, at the least expense of mental energy, demands consideration, and will be found to weigh heavily in our prognosis. All we know is gathered from physical observation, through the medium of the senses; physical alterations in the conditions and relations of parts, can only be determined by sight, touch, and hearing, and the more surely these relations of parts are tested, the more definite will be our opinion. If a man breathe into the Spirometer 200 cubic inches, it is neither 199 nor 201 cubic inches; it requires no delicate training of the judgment, nor sense of sight, to come to such a conclusion; therefore, for the purpose of determining a *fact*, the Spirometer is ready and definite, without a long system of education; but by education, I am inclined to think, it becomes an important means of diagnosis.

180.—I can often guess correctly what a man should breathe in this instrument, by looking at him, though through nervousness he may be deficient. I know it to be from mere momentary want of nervous energy, and not from a want of actual capability, or the effect of organic disease.

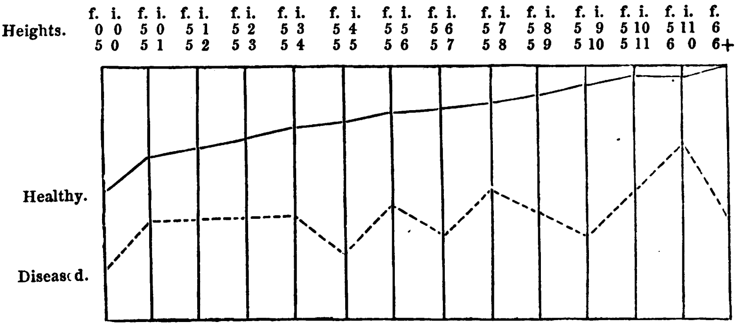
181.—I do not bring this forward with any view of superseding or precluding other physical means of examination, but, on the contrary, I wish to multiply physical observations, because all the deviations of form and volume of the great cavities indicating some abnormal state, are but too much obscured for want of more extended means of definitely examining them.

182.—It will have been observed that the result of the examination of the diseased cases which I have given, particularly that of Freeman's, was to induce a conviction of the usefulness of the Spirometer in an early stage of disease, more particularly in phthisis pulmonalis; and it may be asked, How is it that the difference of the vital capacity should be so great, and the organic disease apparently so little, as not to be detected by the ear? I cannot answer this question with certainty; but I feel strongly disposed to believe that a very small deposition of tuberculous matter will cause a considerable deficiency in the vital capacity.

183.—Writers upon tubercular phthisis lay some stress upon the form and motions of the chest in ordinary and deep breathing; we have seen that in one case (135), the deep inspiration demanded an effort equal to 4½ inches of mercury upon every square inch of the chest, or a total resistance of not less than 300 lbs. to be overcome by muscular power. It is possible that the cachectic condition, in this early stage of the disease, may disable the patient to overcome this resistance, and therefore the vital capacity become diminished by mere want of muscular power.

Diagram 23.

Vital capacity of the healthy and diseased cases compared.



Healthy.	143	175	177	189	193	201	214	229	228	237	246	247	259	276
Diseased.	69	100	101	102	103	78	120	98	130	111	96	130	164	102

184.—The comparative difference of the vital capacity between the healthy and diseased cases may be seen by the two curves (Diagram 23). The lower dotted one is the vital capacity of the diseased, and the upper one that of the healthy. The difference between the relative heights of these lines from the bottom is equal to the difference between the actual quantities given by these two orders of persons. The two rows of figures at the bottom are the mean of the observations under each class. The difference is sufficiently strong to merit consideration. The utility of the instrument for measuring the RESPIRATORY POWER, is probably greater to the army-surgeon than to the man in private practice: I have by it frequently detected hernia, and rupture of the membrana tympani. When a hernia is well supported by a truss, it will most likely escape detection.

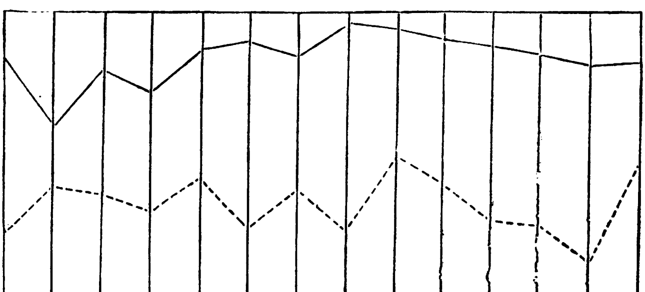
185.—All that has just been said upon mobility, and its relation to visceral disease, will equally apply to the observations on the respiratory power. The efforts required to move the column of mercury tests the whole trunk. The effort of *inspiration* tested on this instrument producing an attenuation, or rarefaction, of the air within the body, causes an extra pressure upon the whole trunk from *without*, the *expiratory* power (one-third more) in a contrary direction from *within*; and as it is a common rule, that inflammation and disease, in general, are attended with pain on pressure, these, also, may be perceived by the diminished power manifested on the instrument which measures the pressure exerted.

DIAGRAM 24.

Inspiratory power of the healthy and diseased compared.

	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.	f. i.
Heights.	0 0	5 0	5 1	5 2	5 3	5 4	5 5	5 6	5 7	5 8	5 9	5 10	5 11	6 0
	5 0	5 1	5 2	5 3	5 4	5 5	5 6	5 7	5 8	5 9	5 10	5 11	6 0	6+

Healthy.



Diseased.

Healthy.	2·55	2·00	2·52	2·31	2·70	2·84	2·70	3·07	2·96	2·91	2·83	2·77	2·65	2·67
Diseased.	·82	1·30	1·16	1·00	1·34	·74	1·25	·79	1·67	1·32	·93	·88	·40	1·65

186.—The difference between the diseased and healthy respiratory power is as widely marked as the vital capacity is by the Spirometer (Diagram 23). This is shown in the same manner by Diagram 24, the lower line being the *power* of the diseased, and the higher that of the healthy. This difference is about one half, as might be anticipated, because weakness is the most prominent symptom of disease. The figures at the bottom definitely show the difference.

187.—During these investigations, the pulse and number of the respirations per minute were taken: the result is contained in the following Tables:—

188.—R.—Table of the Number of Respirations per Minute, in the sitting posture, in 1714 cases.

Number of respirations per minute.	Cases.	Number of respirations per minute.	Cases.	Number of respirations per minute.	Cases.
6	1	20	510	32	6
9	1	21	120	33	0
10	2	22	136	34	1
11	1	23	41	35	0
12	19	24	220	36	1
13	10	25	16	37	0
14	21	26	8	38	0
15	12	27	2	39	1
16	216	28	30	40	1
17	95	29	2		
18	181	30	6		1714
19	70	31	0		

189.—Every one of these respirations was determined without the consciousness of the individual, the observer feeling the pulse with his hand resting on the patient's abdomen, when both the pulse and the inspiration can be numbered. The slowest case was that of 6 per minute: this was a medical gentleman, who had formerly laboured under asthma, but is now quite free from it; since then, his respiration has been thus slow, but deep. The average will be seen as 20 respirations per minute. The following Table is that of the pulse:—

190.—S.—Table of the Pulse per Minute, in the sitting posture, in 1636 cases.

Pulse per minute.	Cases.	Pulse per minute.	Cases.	Pulse per minute	Cases.
48	3	70	57	93	3
49	4	72	44	94	8
50	4	73	58	95	11
51	1	74	32	96	58
52	2	75	11	97	1
53	2	76	118	98	5
54	1	77	2	99	1
56	4	78	38	100	117
57	2	79	7	101	1
58	1	80	315	102	2
59	1	81	3	104	28
60	53	82	28	106	4
62	21	84	167	108	10
63	5	85	2	110	1
64	45	86	25	112	15
65	4	87	2	113	3
66	18	88	88	116	10
67	2	89	16	118	2
68	37	90	31	120	19
69	4	92	76	124	3

191.—The higher range of pulse of course must be attributed to temporary excitement: nevertheless this Table shows that 80 is the prevailing number, and that there are more cases between 80 and 90 than between 70 and 80. The number of respirations per minute are so few and long, that fractions of these movements occur in the minute, though for convenience this is omitted. A deviation from the average by one or two respirations will probably cause a difference of 1800 cubic inches of air passing through the lungs per hour, a quantity too considerable to be overlooked. It therefore becomes necessary to examine into the cause of this increase or decrease, which may exist independently of disease.

It is well known that a sudden difference in atmospheric pressure affects the frequency of the respirations and pulse. Travellers all agree in asserting as a fact, that, when ascending mountains, the diminished pressure accelerates the respirations and pulsations; here the physical exertion required to attain such heights must interfere, concurring with the diminished pressure to quicken these functions; but M. Gay Lussac, in his celebrated aerial voyage to 7000 yards above the level of the sea (almost the tenth part of the *height* of the atmosphere), though exempt from muscular exertion, remaining almost motionless in the car of his balloon, yet experienced a great acceleration of the respiratory and circulatory functions, along with great thirst, which must be considered as the effects of diminished atmospheric pressure.

Through the kindness of my friend Mr. Potter, of Newcastle-upon-Tyne, mining engineer, I was enabled to make the following interesting experiment upon the frequency of the respiratory functions in the deepest mine of that neighbourhood (South Hetton), in December 1845.

Depth of the mine 1488 feet.

	Barometer.	Thermometer.
At the level of the sea	28·72	39°
At the bottom of the mine . .	30·26	49°
Difference	1·54	10 degrees.

T.—Table of the effect of increased Atmospheric Pressure on the Respiratory Functions in Healthy Men.

	Above.		Below.	
	Pulse.	Respirations.	Pulse.	Respirations.
Mr. P.	65	15	59	16
„ S.	98	20	98	24
„ H.	72	16	68	19
„ L.	90	14	88	15
„ W.	88	18·5	93	22
„ T.	85	18	100	20
Mean	83	16·9	84·3	19·3

This experiment was made with *care*: these men had not undergone *any* previous fatigue, therefore the acceleration in these functions is solely due to an increased atmospheric pressure.

Thus we find that an *increased* as well as *diminished* atmospheric pressure quickens the respirations and pulsations; probably this effect in a little time is diminished.

Independently of our ascending or descending to any considerable height or depth, the atmospheric pressure varies in the same locality. The diurnal oscillation from the effect of the sun producing the atmospheric tides * in this country is probably too small to affect the respiratory functions, but the change of pressure produced by meteorological phenomena is considerable. The annual range of the barometer in this country is nearly 3 inches, a tenth of the weight of the atmosphere (2·95), so that our bodies are exposed to a variation of pressure from meteorological causes alone, exceeding 3000 lbs. (3313·440 lbs.) or 23 ounces on every square inch of the body. Now, according to my experiment in the coal-mine, the sudden augmentation of pressure from an excess of 1488 feet of air was little more than half this, and therefore so much within the limit of natural atmospheric variations as common to our climate. If we take the increased pressure at this depth as the 20th of an atmosphere, the pressure upon these men would be about 11 ounces (11·70 ounces) on the superficial square inch, or a total weight exceeding 1500 lbs. (1611·67 lbs.), which affected the respiratory functions as follows:—

U.—Table of the effect on the Respiratory Functions under the sudden increase of the 20th of an atmosphere in descending 1488 feet.

	Pulse per minute.	Respiration per minute.
Mr. P.	− 6	+ 1·0
,, S.	0	+ 4 0
,, H.	− 4	+ 3·0
,, L.	− 2	+ 1·0
,, W.	+ 5	+ 3·5
,, T.	+ 15	+ 2·0

* "At two periods in the day, at every part of the world, and nearly at the same time of the day, the barometer attains a maximum and minimum as the effect of tides in the atmosphere. If the height of these tides be proportional to the difference between the specific gravity of air and mercury, the morning tide will be about 13 feet, and the evening tide 25 feet."—Thomson, on Heat, p. 240.

The effect on the pulse is irregular; the respirations are universally accelerated, on an average, about one-eighth, a difference which merits consideration.

I believe a difference equal to this may take place as the effect of natural changes in the atmospheric pressure. I have experienced strange sensations and lassitude, &c., under the sudden fall of nearly six-tenths of an inch in the barometer, which once took place within three hours. It is well known how susceptible some persons are to changes in the weather: a day is called heavy, when in truth it is lighter, while we ourselves are heavier; a transient plethora is produced, the blood-vessels become more distended, and the least exertion produces perspiration. Duhamel observed, that in the month of December 1747, the barometer, in less than two days, fell $1\frac{1}{3}$rd of an inch, producing a change on each man of 1400 lbs., which difference was accompanied with many sudden deaths. When the barometer is very high, we generally experience an indescribable sensation of pleasure; the vital energies seem doubled.

Other meteorological causes may interfere concurrently to affect these functions more or less, yet the atmospheric pressure is so easily measured, and so *evidently a modifier* of respiration, that before we determine the breathing movements, as above or below par, the barometer should be noticed.

The effect of *diminished* atmospheric pressure upon the action of the heart and arteries appears more regular than when under an increased pressure. According to Dr. Parrot, a rarified atmosphere influences these functions as follows:—

V.—Table of the effect of diminished Atmospheric Pressure on the Heart's action.

							No. of beats.
Pulse at the level of the sea							70
At 1000 metres, or 3280 feet, 10·29 inches above the level of the sea							75
At 1500	,,	4921	,,	3·43		,,	82
At 2000	,,	6561	,,	8·58		,,	90
At 2500	,,	8202	,,	1·72		,,	95
At 3000	,,	9842	,,	6·87		,,	100
At 4000	,,	13,123	,,	5·16		,,	110

According to this Table the pulse increases 40 beats at the elevation of 4000 metres, or on an average of 1 pulsation per 100 metres (328 feet 1 inch). By the first 1000 metres it rises 1 pulse per 200 metres (656 feet 2 inches).

I am inclined to think this effect is too small to become apparent by diminished pressure from meteorological causes, because, at an elevation of 2000 feet, little more than 600 metres, the barometer, according to Halley's calculation, would stand at 27·86 inches, and I believe this instrument in England never descends to 28 inches, which is an equivalent to an elevation of 1862 feet; therefore a sudden fall of the barometer to its lowest limit would not affect the pulse probably above 2 or 2½ beats per minute: this is even supposing a case of which I believe there is no record.

192.—Many curious combinations may be made from this paper; thus, 1939 men can breathe 431,323 cubic inches, or 31 hogsheads of air, or a little more than 2½ cubic feet for each man per minute, by the greatest voluntary effort.

In this age for promoting ventilation in public buildings, a quantity bearing no relation to this has been thought necessary, which, if not deleterious, has at least been found disagreeable.

I see also that, in the Model Prison, "from 30 to 45 cubic feet of pure fresh air is made to pass into every cell in a minute," "ranging from a temperature of 52° to 60°."*

193.—Another circumstance I have been led to observe, which may be found useful in saving life. We see the vital capacity is, on an average, 225 cubic inches; consequently we possess a power at any time of taking in this stock of fresh air, which may be considered as a reservoir to support life without breathing. Therefore, if we expel from the lungs four or five times the old reserve air which previously remained in the chest, then draw in this 225 cubic inches, or more, according to our vital capacity, and hold the breath, *it will be found we can exist upon this without discomfort* (except for the first few seconds) *three* times as long as any other way. In this way I have seen a man hold his breath two minutes, which (it is said) is the longest time the most expert pearl divers remain under water. "Mr. Brunel, in descending to examine the breach which the river had made in the Tunnel under the Thames, having lowered the diving-bell nearly 30 feet to the mouth of the opening, this was found too narrow to admit the bell, so that no further observation could be made on the state of the shield and other works, which were perhaps 8 or 10 feet deeper. Mr. Brunel therefore, laying hold of the rope, left the bell, and dived himself down the opening; his companion in the bell being alarmed at the length of his stay, now *about two minutes*, gave the signal for pulling up, and the diver, unprepared for the signal, had hardly time to catch hold of the rope which he had let go, and was surprised on coming up to find that so much time had elapsed. On descending again, he found that he could with ease remain *fully two minutes under water!* The reason evidently was, that the atmosphere in the bell being condensed by a column of water nearly 30 feet in height, contained nearly double the quantity of air

* Report of the Surveyor-General on the Construction, Ventilation, &c., of Pentonville Prison, 1844, p. 25.

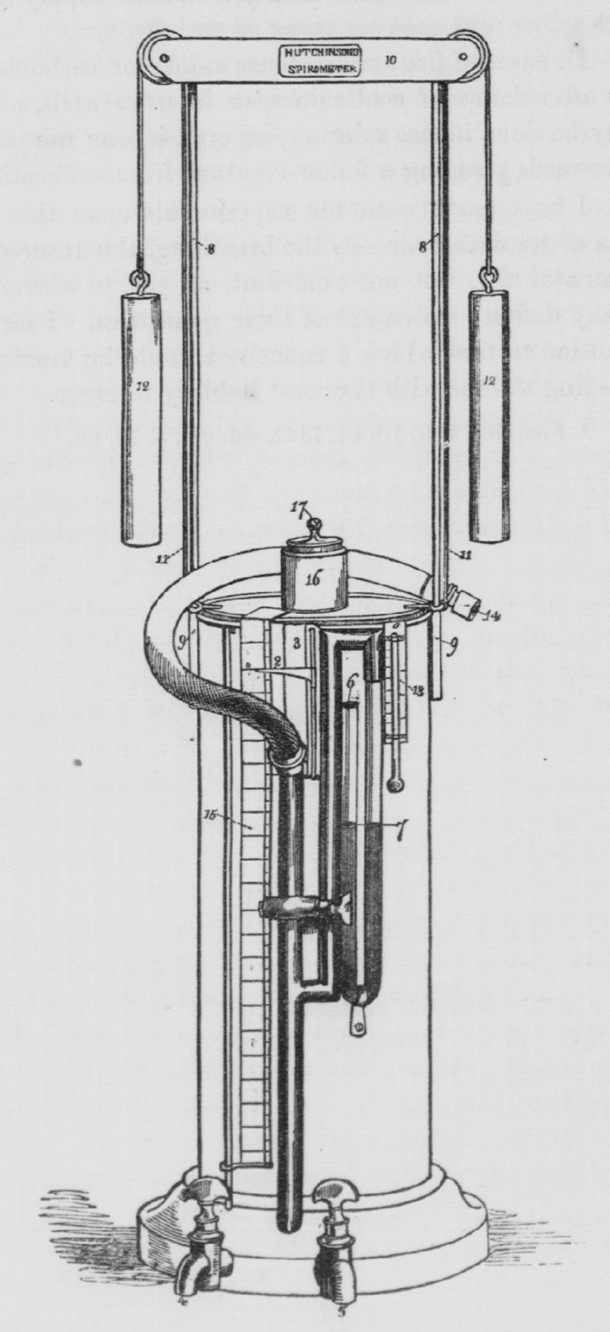
to the same bulk, and thus nearly a double supply in the lungs."*

194.—In cases of fire amidst dense smoke or carbonic acid gas, the after-damp of coal mines, or in draw-wells, a great deal may be done in *two* minutes, or even in one minute and a half, towards rescuing a fellow-creature from suffocation.

195.—I have made some few experiments upon the other divisions of respirable air—as the breathing, the reserve, and complemental airs, but not sufficient, as yet, to warrant my giving any definite statement of their quantities. I directed my attention to that which I conceived would be most useful for detecting disease with the least liability to error.

* Encyclop. Brit, 7th ed. 1842, vol. viii. p. 59, 60.

Diagram 25.



197.—Directions for measuring the vital capacity of the lungs, together with making other observations.

To prepare the instrument for use.

1. Place the Spirometer about three feet from the ground, on a firm, level table.

2. (See Diagram 25.) Turn off the *water* tap, fig. 4, and turn open the *drain* tap, fig. 5, seen at the bottom of the Spirometer.

3. Pour into the spout at the back, clear, cold water, until it is seen to rise behind the slip of glass, fig. 3, placed above the air-tube.

4. Slide the moveable index, fig. 2, opposite 0 on the scale, and add water until it is exactly on a level with the straight edge of this index. Should too much water be already poured into the Spirometer, draw off by the tap, fig. 4, sufficient to bring the water down to the edge of the index.

5. Pour a little coloured spirit into the bent tube, fig. 6, until it rises in the two legs of this tube about 3½ inches, as represented by fig. 7.

6. Fix the rods, fig. 8, into the sockets, 9, 9, on each side, at the top of the Spirometer.

7. Place upon these rods the cross-head, fig. 10, so that the name of the instrument faces the operator; then pass the two red cords, figs. 11, 11, over the pulleys at each end of the cross-head.

8. Turn off the taps, figs. 5 and 1, then suspend the counterbalance weights, figs. 12, 12, to the red cord.

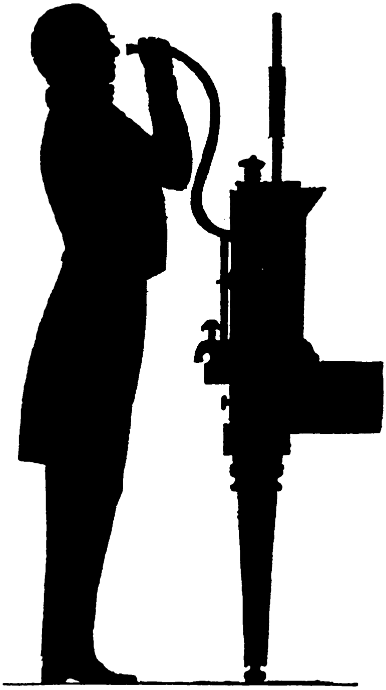
9. Screw the flexible tube, fig. 14, on to the extremity of the air-tube, above the tap, fig. 1. The tube is here turned over the instrument for convenience in the drawing.

10. The small thermometer, fig. 13, may either be attached to the Spirometer on the little hook above fig. 13, or, which is better, hung up in any convenient corner of the room.

The Spirometer is now ready for making an observation.

DIAGRAM 26.

Position of the body in filling the chest before breathing into the Spirometer.



To measure the vital capacity of the lungs.

198.—When the vital capacity of the lungs is to be made (33), let the person to be examined loose his vest, *stand perfectly erect*, with the head thrown well back, as represented by Diagram 26; then *slowly* and *effectually* fill his chest with air, or *inspire* as deeply *as possible*, and put the mouthpiece (fig. 14, Diagram 25) between the lips (standing in the same erect position), holding it there sufficiently tight as not to allow any breath to escape; the observer in the mean time turns open the tap, fig. 1: immediately the patient empties his lungs, and *slowly makes the deepest expiration*; at the *termination* of which the operator turns off the tap, fig. 1, confining in the receiver the expired air, which part of the Spirometer is now raised out of the reservoir, as represented in Diagram 27, fig. 20.

199.—To measure the quantity of air breathed into the Spirometer, the receiver must be depressed lightly with the hand until the two surfaces of the coloured fluid in the bent tube are brought level with each other, as seen fig. 7, Diagram 25. When these are equal, the straight edge of the index, fig. 2, may be slid to the level of the water, seen through the slip of glass, fig. 3, when it will cut the degree upon the scale which numbers the cubic inches of air breathed from the lungs.* Each degree upon the scale measures two cubic inches. Thus is determined the *vital capacity* of the lungs.

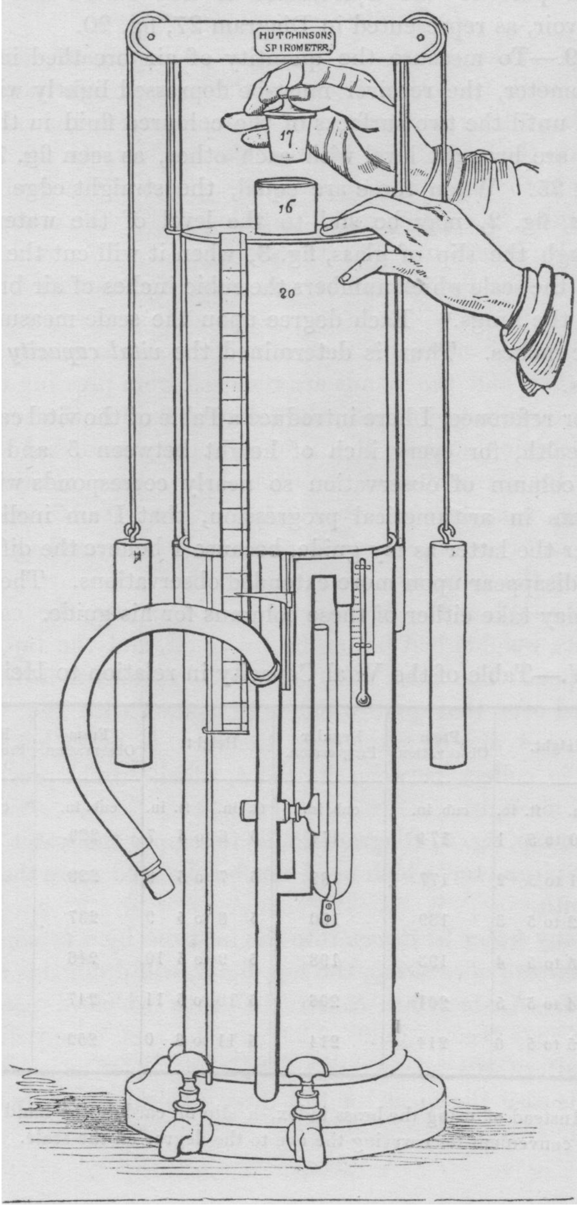
For reference, I here introduce a Table of the vital capacity, in health, for every inch of height between 5 and 6 feet. The column of observation so nearly corresponds with the column in arithmetical progression, that I am inclined to prefer the latter as my guide, because I believe the difference will disappear upon more extended observations. The operator may take either of these columns for his guide.

W.—Table of the Vital Capacity in relation to Height.

Height.	From Observation.	Regular Progression.	Height.	From Observation.	Regular Progression.
ft. in. ft. in.	cub. in.	cub. in.	ft. in. ft. in.	cub. in.	cub. in.
5 0 to 5 1	174	174	5 6 to 5 7	229	222
5 1 to 5 2	177	182	5 7 to 5 8	228	230
5 2 to 5 3	189	190	5 8 to 5 9	237	238
5 3 to 5 4	193	198	5 9 to 5 10	246	246
5 4 to 5 5	201	206	5 10 to 5 11	247	254
5 5 to 5 6	214	214	5 11 to 6 0	259	262

* Instead of using the brass index, a slip of card in the hand is often more convenient for carrying the eye to the degree on the scale.

DIAGRAM 27.



To discharge the air out of the receiver.

200.—Take *out* the valve, fig. 17, Diagram 27, with one hand, while the other depresses the receiver into its original position, taking *particular care,* before returning the valve, fig. 17, into the socket, fig. 16, that the receiver, fig. 20, is perfectly at the bottom, *and* that the surfaces of the fluid in the bent tube, fig. 7, Diagram 25, are level with each other *before* the valve is returned into its socket.

201.—The Spirometer is now ready for another observation.

It will be observed that, after the valve is returned into its socket, and the hands are removed from pressing the receiver down into its place, the coloured fluid in the bent tube will become unequal; that is of no consequence, and will not affect the correctness of the next observation: always recollecting, *immediately* before examining a case, to open the valve and press the receiver perfectly down, *previous* to returning the valve, as already described.

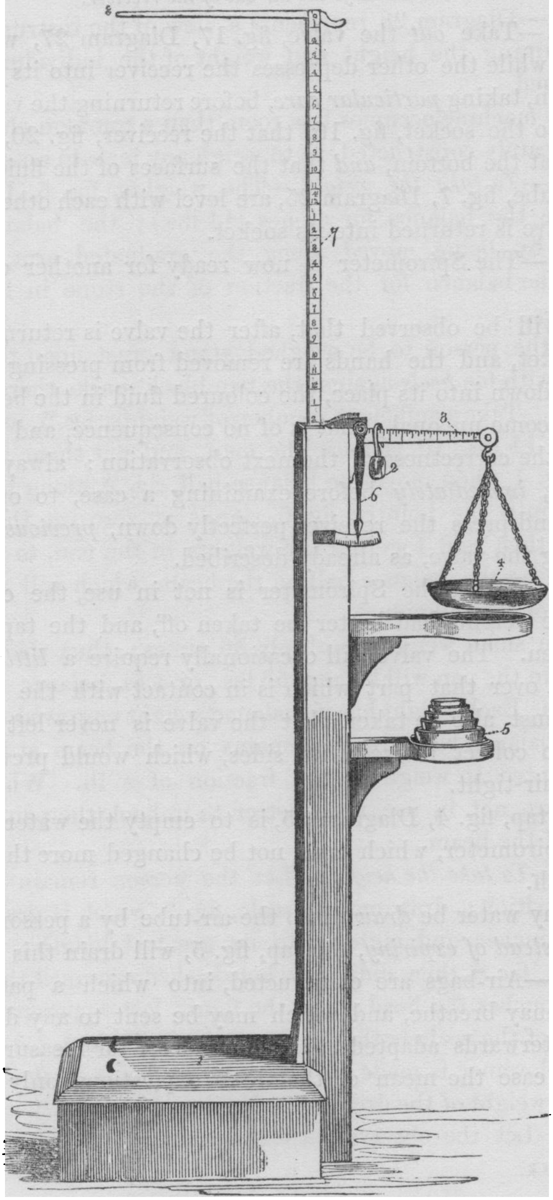
202.—When the Spirometer is not in use, the counterbalance weights had better be taken off, and the tap, fig. 1, left open. The valve will occasionally require a *little* tallow rubbed over that part which is in contact with the socket; *care* must also be taken that the valve is never left out for dust to collect between its sides, which would prevent its being air-tight.

The tap, fig. 4, Diagram 25, is to empty the water out of the Spirometer, which need not be changed more than once a month.

If any water be *drawn* into the air-tube by a person *inspiring instead of expiring,* the tap, fig. 5, will drain this off.

203.—Air-bags are constructed, into which a patient at home may breathe, and which may be sent to any distance, and afterwards adapted to the Spirometer for measurement; in this case the mean of the three expirations only can be taken.

DIAGRAM 28.



Height and Weight.

204.—Diagram 28 represents a view of the instrument for determining the height and weight of the individual to be examined.

This machine occupies less room than a common chair, and so delicately constructed, as to weigh any man to an ounce.

205.—*To take the weight.*—The weights, fig. 5, Diagram 28, are the balance for stones (14 lbs.); the balance-ball, fig. 2, by being moved along the graduated arm, fig. 3, gives the balance for the fraction of the stone in lbs. and quarters.

Let the person to be weighed stand erect upon the part, fig. 1, with his *heels* against the two black marks there represented. Take a sufficient number of weights, fig. 5, as nearly (within 14 lbs.) to balance the man, and put them into the pan, fig. 4, then move the balance-ball, fig. 2, along the arm, fig. 3, until the pointer, fig. 6, stands at zero on the ivory scale; then add together the weights in the pan, to the lbs. marked by the balance-ball on the beam, which will give the weight of the individual.

These small weights multiply 56 times; thus the 16 oz. weight in the pan will balance 56 lbs., or 4 oz. balance 1 stone, or 14 lbs. Each weight has its balance-weight engraved upon it.

The balance-ball always remains on the beam at 0 when not wanted to weigh to the fraction of a lb. When the scales are not in use, it is better to unhook the pan, fig. 4, from off the beam.

206.—*To take the height.*—Let the person remain in the same position; draw out the scale, fig. 7, which is graduated to feet, inches, and eighths, to its greatest length; extend the arm, fig. 8, then slide the whole scale down until the arm, fig. 8, touches the head; and the figure last apparent at the bottom of the scale is the height of the individual.

No allowance is made for the ordinary boots or shoe-heels, nor the weight of the dress. See Note, p. 165 (M. Quetelet).

207.—Let the observation for measuring the "forced expiration" be made *three* times, and the greatest of them be noted as the "Vital Capacity" (31).

208.—The observations made upon the person (28), are as follows:—

Vital capacity, power of inspiration, power of expiration, height, weight, circumference of the chest over the nipples, pulse and respirations per minute (sitting), greatest mobility of the chest, age, and temperature of the room.

The power of inspiration and expiration is determined by another instrument, which is most useful for army-surgeons.

209.—*Order of taking the observations* (208).

1st and 2nd.—Of the pulse and number of respirations per minute.—Place the person to be examined on your right side, reclining at his *ease* on a chair; feel the right pulse in the usual way, with your right hand at the same time resting on his abdomen: in this position you may both count the pulse and number the respirations.

210.—3rd.—*Of the circumference of the chest.*

This is taken by a common tape measure passed round the chest over the region of the nipples, allowing a quarter of an inch for the shirt, and a quarter for the flannel.

211.—4th.—*Of the mobility of the chest* (70).

When the ordinary circumference of the chest has been taken, keeping the tape measure on the same region, request the person forcibly to expire, and note this minimum circumference; then request him to inspire, or fill his chest as much as possible, noting the maximum circumference—the difference between this and the minimum, I designate the mobility of the chest.

This, in healthy persons of ordinary weight and middle age of life, averages three inches—seldom attaining four inches. I have had two cases attaining five, and one six and a quarter inches; these men in consequence measured a vital capacity exceeding 300 cubic inches.

212.—5th.—*Of the height and weight.*—See 206, 205.

213.—6th.—*Of the vital capacity.*—See 198.

214.—7th.—*Of the respiratory power.*

This is measured by an instrument constructed for the purpose (122), a tube from which is to be closely applied to the nostrils by the person making the observation, requesting the party examined to inspire *slowly*, and with his greatest effort. The index of the instrument or column of mercury will point out on the scale the inspiratory power.

215.—The expiratory power is measured in the same way, only with a diametric movement, requesting the person partially to fill his chest with air, and *slowly* to expire with his *greatest* effort.

216.—The mercury should not be jerked upwards or downwards, but slowly acted upon, which will easily be known by its tremulous motion when the greatest muscular power is in operation. This operation is not dangerous; 2000 cases so tested, without any ill effect, warrant me to state this.

217.—It is wonderful to consider that this exertion, when applied by nature, though so considerable (145), is not injurious to the air-cells of the lungs, yet the finest injection, applied with every precaution and skill, will almost universally rupture these delicate cells.

218.—This liability to rupture may probably be accounted for in two ways:—1st. By art, we *over-distend* the lung. 2nd. We apply the power from within. In nature, we neither over-distend the air-cells of the lungs, nor do we apply any force to the inner surface of the air-cell, inspiration being the simple act of the parietes increasing the boundaries of the thoracic cavity.

219.—*To correct for temperature the air breathed into the Spirometer.*—We may estimate the change in the bulk of air as $\frac{1}{500}$ for every degree (F.) of variation of temperature; thus, if a man breathe, in winter, 295 cubic inches of air into the Spirometer, when the thermometer in the room stands at 55°, being 5 degrees below 60°, then $\frac{5}{500}$ must be added to the 295 cubic inches; thus, $\frac{5}{500} = \frac{1}{100} \cdot 295 \times 1 = 295 \div 100 = 2{\cdot}95$ cubic inches, added to $295 = 297{\cdot}95$, or, in round numbers, 298 cubic inches. On the other hand, if the vital capacity be determined as 215 cubic inches when the thermometer stands at 72°, which is 12 degrees *above* 60°, $\frac{12}{500}$ must be deducted; thus $\frac{12}{500} = \frac{1}{42}$. 215 × 1 = 215 ÷ 42 = 5 cubic inches to be subtracted, making the corrected observation as 210, instead of 215 cubic inches. In a little time the operator can make these corrections without pen or paper. Every one of the observations I have made, has been corrected for temperature.

As it is absolutely necessary that, for comparison, all cubic measurements of air should be as nearly of the same temperature as possible, I purposely constructed the Spirometer to hold a vast quantity of water, because it will be found, during the greater part of the year, our inhabited rooms are generally at the temperature of 60°; thus the water in the Spirometer at these times reduces the observations to 60°, without any other correction. In fact, it is only in the extremes of the seasons, when the water in the Spirometer considerably differs from 60°, that correction for temperature is required. The temperature should always be considered when a suspicious case is examined, to give the individual every advantage.

When all these observations are made (208), and noted in a book properly headed, the state of the person examined is then expressed in the unerring measure of figures—which immediately presents to the eye a certain state of things.

The great epoch in the history of chemistry was the introduction of the atomic theory, the laws of combination and the doctrine of equivalents, founded only upon experimental evidence, and not involving hypothesis.

For a starting point, an arbitrary figure is chosen, from which every combining proportion is relative, and, though the doctrine of atoms and half atoms is beyond our powers of comprehension, yet this arbitrary measure affords a luminous explanation of the laws of the combination of matter. Again, the meteorologist would be quite at a loss to describe the various states of the weather without expressing the same in the definite measure of figures. Just in like manner may the ever-changing qualities of the human functions be expressed. I will here introduce a Table of the comparison of different persons examined, which will at once present to the eye a certain difference of constitution. This difference is no mere theory, but is the expression of a number of facts, which must lead to some sure conclusion :—

Table X.—The Comparison of different Persons in Health and Disease. (Males.)

Initials.	Vital Capacity.	Temperature of the Spirometer.	Power of Inspiration.	Power of Expiration.	Circumference of Chest.	Mobility of Chest.	Respirations per Minute, Sitting.	Pulse per Minute, Sitting.	Height.		Weight.		Age.	Remarks.
									ft.	in.	st.	lb.		
A.	245	60	3·20	5·50	38¼	3½	20	80	5	9	12	9	28	Wrestler.
B.	290	60	3·50	5·30	41	3¼	20	83	6	1	13	8	21	Soldier, H. G.
C.	228	60	3·70	4·20	34	3	18	79	5	6	10	11	23	ThamesPolice.
D.	464	60	3·15	3·70	50	4	16	78	7	0	21	8	27	Giant.
E.	80	60	3·00	3·74	29	3	29	102	3	9¾	4	7½	35	Dwarf.
F.	108	60	0·75	0·46	35¼	1½	40	60	5	11	10	0	60	Phthisical.
G.	80	60	1·50	2·00	35	1	40	100	5	9	10	0	36	Ditto.
H.	260	60	0 50	1·30	34	3¼	21	64	5	7	10	1	29	Tympanum ruptured.
I.	222	60	0·50	1·00	34½	3	16	80	5	6	10	4	40	Hernia.
J.	186	60	0·70	0·80	36	1½	28	100	5	8	10	3	30	Incipt Phthisis

Thus is expressed, as an illustration, the result of this method of observation upon cases I have actually examined.

The eye at once will perceive a great difference in these 10 persons.

The first three are healthy cases; the vital capacity corresponds with the height according to the rule laid down. (Table W., p. 237.)

The inspiratory and expiratory powers are considerable, and bear a proper relation to each other.

The mobility of the chest is also natural, and the weights are indicative of health.

Therefore it may safely be said, these three men have healthy lungs, or, at least, permeable to air throughout their entire extent. Their respiratory power is indicative of great physical strength.

The fourth case (D.) has a remarkable vital capacity; but his height is 7 feet. The respiratory *power* of this man is below par, particularly his expiratory power, indicating that there is some cause existing which prevents his expiratory muscles acting with healthy vigour.

The next case, though only measuring a vital capacity of 80 cubic inches, was of short stature (3 ft. 9¾ in.). This little man's respiratory power was better than the case of D., though his pulse and respirations per minute were certainly objectionable—he is now dead.

F. and G. are examples of persons labouring under phthisis. The stature shows that their vital capacity is *very* much below the natural standard: instead of 108 it should have been 254, and, instead of 80, 238 cubic inches. Their respiratory *powers* are also much too low—the thoracic mobility two-thirds below the standard, and the respirations 40 in the minute.

In casting the eye along the line of figures in the case of H., the striking part is the respiratory power, which is so deficient, while every other observation looks healthy: this was a case of rupture of the membrana tympani. When this man *closed* his ears, his respiratory power was manifested as nearly *three* times as strong.

In the case of I., the respiratory power is deficient, from hernia being present.

The last is a case of phthisis in an *early* stage: the measures here are sufficiently marked to excite attention.

The fixed point from whence I judge of the excess or deficiency of a case is from the height; this never varies but in the extremes of age, therefore stature presents a sure guide upon which to ground an opinion. (Compare the vital capacity Table X., p. 245, with Table W., p. 237.)

Before I conclude, I may venture to draw the attention of those connected with insurance offices to the matter of this paper. Thus, the state of a man examined, and appearing like the three first cases in Table X., would admit of little doubt but that such was an assurable life, while the other cases would be suspicious. From such a table of facts, any man can form his own judgment of a case, without being dependent on the opinion of another. Therefore, to insurance offices, as well as to the medical profession, the Spirometer, I think, would be found useful.

EPITOME.

Nothing rightly was known upon the functions of the respiratory organs previous to the discovery of the circulation of the blood, the pressure and composition of the atmosphere (1, 2).

Of the mechanical division of respiration (3).

To comprehend the function of respiration, the breathing act must be divided into different heads (4, 5, *et seq.*), which is here illustrated by a Diagram, (10,) and their characteristic differences described (12).

The subject of this paper resolves itself under seven heads (15).

First.—*Of the quantity of air expelled from the lungs in connection with other physical observations on the human frame* (16).

The observations hitherto made upon the subject appear discrepant (17 *et seq.*) for obvious reasons (22-26), and how such can be avoided, not only in considering respiration, but any other physiological or pathological research (27).

Many other points besides the one here sought for have been observed (28), in the various classes examined (30).

Of the vital capacity.—This differs in man according to height, weight, age, and disease (35).

By *height*, in the arithmetical relation of 8 cubic inches for every inch of height between 5 and 6 feet (36-41).

By *weight*, at 5 feet 6 inches it decreases 1 cubic inch per lb. between 11½ and 14 stone (53-56). At other heights 7 per cent. must be added (60) to the weight given in Table G., p. 166. The weight increases in a certain relation with the height in 3000 cases examined (58 *et seq.*, Table F., p. 165). The weight may be calculated from the height (59).

Table of the effect of weight on respiration (pp. 162 and 163), shown also by a Diagram (p. 164).

By *age* (61).—Age, after a certain time, decreases the vital capacity, as shown by Tables I. and J., (p. 170 *et seq.*), and by a Diagram (p. 172). The decrease is nearly 1½ inch per year between 30 and 60 years of age (64).

By *disease*, the vital capacity decreases from 10 to 70 per cent. (163 *et seq.*; Table, p. 156; Diagram, p. 224; Table, p. 218; also the 7th head, Practical Remarks, p. 216).

Second.—*Of the absolute capacity of the thorax, and its various dimensions* (73; see Table, p. 176).

The size of the chest, and the quantity of air a man can breathe, have no direct relation with each other (73 *et seq.*).

The circumference of the chest, also, has no relation to the vital capacity (Table K., p. 173); but it has an exact relation to the weight, increasing 1 inch for every 10 lbs. (71; Table D., p. 162; dotted line in Diagram 3, p. 164).

A stout man may have large lungs, and a spare man may have small lungs; there appears no relation between the cubic space in the thorax and the weight. See Table L., p. 176, and then compare the 5th column with the 18th.

The size of the chest, and its mobility, bear a strict relation to the quantity of air we breathe; a 40-inch chest, with 3 inches mobility, will breathe less in a deep expiration than a 40-inch chest with 4 inches mobility (70, 92, 107, 117, 178).

The cubic mobility may exceed the cubic cavity of the chest (79).

There is no relation between the height and the cubic dimensions of the thorax (Table L., p. 176; compare the 4th column with the 18th).

There appears no relation between the sitting and standing height (90).

Third.—*Of the respiratory movements, &c.* (90.)

The ordinary breathing in the two sexes differs (113). In men it is chiefly by the diaphragm (97, 98, 112); in women chiefly by the ribs (113).

Extraordinary breathing is the same in the two sexes (dotted line, Diagrams 13 and 19;)—(100, 113).

When we examine the breathing movements, the position of the body must be considered (116).

The chest in inspiration does not increase its dimensions equally on all sides (Diagram 14, fig. E;)—(104 *et seq.*; 140).

It is questionable whether the diaphragm descends in the act of *deep* inspiration (102-104).

The breathing movements in the male shown by Diagrams 13, 16, 17, 18; female, 19, 20.

In deep expiration the body shortens (110, 115).

Fourth. — *Voluntary inspiratory and expiratory power* (119, 121, 144).

The expiratory power is manifested greater than the inspiratory; (122-126; 146; Table M., p. 201).

A certain relation exists between the height and the inspiratory power (124; Diagram, p. 202).

The power of the respiratory muscles is very considerable (143 *et seq.*); case of the greatest power nearly equal to 2 tons (147).

In testing the respiratory power by suction, the hydrostatic law of the pressure of fluids must be considered (144; note, p. 198).

Fifth.—*Of the elasticity of the ribs and voluntary respiratory power* (127).

Great difference manifested between the inspiratory and expiratory power, chiefly due to the elasticity of the ribs (131 *et seq.*); their power measured (134); their power in the different inspiratory stages calculated (138 *et seq.*).

The voluntary and elastic power is combined in expiration, but antagonise each other in inspiration (146).

Sixth.—*The effect of decussating diametric and oblique power in reference to the function of the intercostal muscles* (148).

The external intercostal muscles are inspiratory, and each muscular lamella takes its fixed point from the rib next above, to elevate the rib below (152).

The ribs decussate in inspiration, and converge in expiration (155).

Seventh.—*Practical deductions* (p. 216).

Cases given, illustrating the use of the Spirometer as a means of detecting disease (156 to 175). Table of observations in phthisis pulmonalis (p. 218).

The vital capacity and the respiratory power of the healthy and diseased compared (Diagrams 23 and 24, p. 224). Table of the vital capacity in health, for reference (p. 237).

The natural number of respirations and pulsations per minute (187 *et seq.*).

They may be affected by sudden changes in the atmospheric pressure. The result of an experiment is given in descending a coal-mine, where the respirations are quickened (191 *et seq.*). The effect of atmospheric pressure appears less regular upon the heart's action. Diminished atmospheric pressure is probably too little, from meteorological causes, to be observed by the pulse (p. 230).

How to hold the breath nearly three times longer than natural (193).

Directions for using the instrument in measuring the vital capacity, &c. (p. 235). Arranging the Spirometer, with a sketch of this instrument (p. 235).

The attitude of the body described by a sketch, when about to measure the vital capacity (p. 236), with a Table of reference (p. 237).

A convenient method of determining the height and weight, with a sketch of the scales, &c. (p. 241).

The order of taking the collateral observation (209 *et seq.*), and rule for making the corrections for temperature on the respired air, the vital capacity here being invariably expressed as at 60° (F.) (219).

Method here recommended of expressing the different conditions of the human frame by figures (p. 244 *et seq.*), with an illustration given in a tabular form (Table X., p. 245), and remarks upon these cases.

The matter of this communication is founded upon a vast number of facts—immutable truths, which are infinitely beyond my comprehension. The deductions, however, which I have ventured to draw therefrom, I wish to advance with modesty, because time, with its mutations, may so unfold science as to crush these deductions, and demonstrate them as unsound.

Nevertheless, the facts themselves can never alter, nor deviate in their bearing upon respiration—one of the most important functions in the animal economy.