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(8)

HUMAN LOCOMOTION;

HOW WE STAND, WALK AND RUN.

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The second of the course of scientific lectures before the American Institute was delivered Tuesday evening, December 27th, 1870, in the Academy of Music, by Prof. Burt G. Wilder, of Cornell University. It was very profusely illustrated, and interesting practical experiments attested the truth of the lecturer's statements. Prof. Wilder said:

Ladies and Gentlemen.—During the past year I have spoken four times upon the subject of this evening's lecture; twice in Boston before the Lowell Institute,* and twice before my classes in the Cornell University.

The first time, I thought I understood the subject very well; but at each repetition I perceived more clearly the existence of matters which I could not explain, and to-night I freely admit that the points which are perfectly clear to me are vastly fewer than those which remain to be investigated.

You are incredulous as to there being anything abstruse or difficult to understand in the subject of human locomotion. "Anybody can stand; a very Hottentot can walk about; and the beasts themselves get over the earth after their fashion, occasionally even upon two legs like ourselves." Very true, but no one has heard a gorilla or a bear or an ostrich lecture upon the subject of bipedal progression; yet they employ it constantly or upon occasion; we all see and hear perfectly well; so does the most degraded savage, even better than ourselves; and yet, at the present time, the most learned physiologists are in doubt respecting the exact nature and functions of certain

* In a course of lectures upon Hands and Feet of the Mammalia, Jan. and Feb. 1870.

structures in the eye and the ear; every child knows a mosquito, and no very profound erudition is required in order to be bitten by one; but how few of us have any idea of the complicated apparatus by which our skin is pierced, the blood withdrawn, and poison instilled into our veins; and finally, wise as we think ourselves, big as we are now, and firm as we are upon our legs, there was a time when, as our parents will testify, we could not even stand upright; and we have gained the power to stand, to walk and to run, only by long practice, at the expense of much time and many hard knocks.

Dr. Holmes says: *"Walking is a perpetual falling with a perpetual self-recovery. It is a most complex, violent and perilous operation, which we divest of its extreme danger only by continual practice from a very early period of life. We find how complex it is when we attempt to analyze it. We learn how violent it is, when we walk against a post or a door in the dark. We discover how dangerous it is, when we slip or trip and come down, perhaps breaking or dislocating our limbs, or overlook the last step of a flight of stairs, and discover with what headlong violence we have been hurling ourselves forward." Of the complexity of walking, there can be no doubt, and I am convinced that if any ten now before me should undertake to come forward now into my place, and tell all the rest how they stand and how they walk, they would in the first place offer you as many contradictory explanations of the phenomenon, and if any one undertook to give the lecture over again he would contradict himself as flatly as I did when I delivered it for the second time. Now, granting all this, it is certain that I am not here to say everything that is or can be known respecting human locomotion.

How we Stand Upright.

Whatever be the mental and spiritual distinctions between man and beast, there is no doubt that the human body differs less from the body of a gorilla than this does from some of the lowest monkeys; the gorilla even stands upon its feet and "apes" mankind. But neither it nor any other ape or beast whatever stands *erect* like man; for in none of them are the head, trunk and legs so arranged as to be balanced one above the other in the same plane. This is the case in man alone. The human body is a perpendicular column composed of several segments which are accurately balanced upon each other. The head rests upon the spine in such a way that it tends to fall forward when we are asleep, rather than backward; but with all ani-

* The Human Wheel, its Spokes and Felloes; Atlantic Monthly, May, 1863.

mals the jaws are so large and the point of attachment of the head to the spine is so far back that there is no balance whatever, and the weight of head requires large muscles in the neck; that we have no such muscles is evident when we get upon "all fours," for then the effort to keep the head raised, or in the position of a quadruped, is very fatiguing. In the gorilla, again, the spinal column itself forms but a single curve from the skull to the pelvis; but with man, it forms several curves, which compensate each other, and so becomes an elastic rod to lessen the jar in walking, while yet the place of attachment to the hip bones is just under the point supporting the head.

The hips themselves are so inclined forward that the whole trunk is balanced upon the heads of the thigh bones, and the legs, instead of being bent, as with most animals, are fully extended, so that hip, knee and ankle joints all lie nearly in the same plane, and the weight of the whole body comes upon the key-stone of an arch formed by the heel behind and the ball of the foot in front.

But a flexible column, such as has been described, with its heaviest parts above the middle of its length, would at once collapse and fall to the ground unless supported in some way; and so we find that on all sides the segments of the legs and of the head and spine are braced by muscles, which are in a state of constant though unconscious contraction, so as to maintain us in the erect position, while their power is so great, especially of those forming the buttocks, as to enable us to stand upon one foot and bend the body and leg, while supporting a heavy weight.

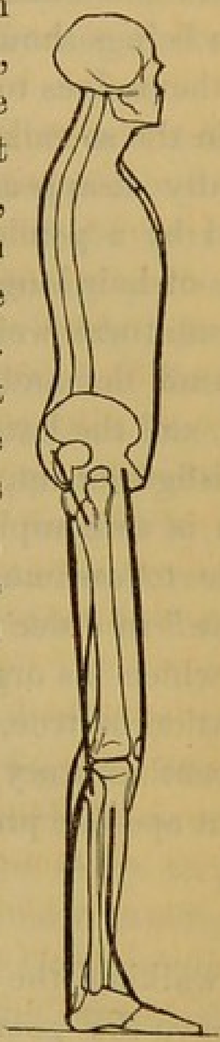

Fig. 1. Diagram of man in the erect position, showing the position of the joints; the darker lines represent the muscles which preserve the balance.

Now all this has been often and well described, and I have spoken of it here partly to introduce the less perfectly understood subjects which follow, but chiefly to call attention to the fact that while many animals stand upon two legs, and may even approximate the erect position, yet man alone assumes it naturally and perfectly, his whole frame being adapted for it in a way not elsewhere seen. There is great significance in the erect position of man, for though it may differ but little from a slightly inclined position, yet that difference is like that

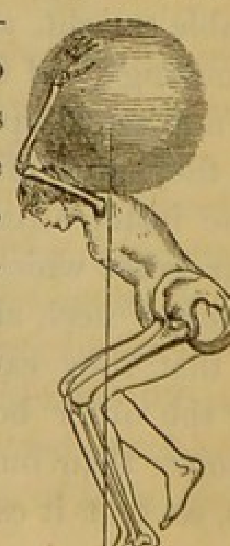

Fig. 2. Diagram of a man bearing a heavy weight, and yet keeping his center of gravity over the point of support in the ball of the foot.

which separates the "just right" from the "nearly so," and causes the human body to point straight upward, while the fishes are horizontal and the other vertebrates seem to be striving in vain to raise their heads away from the earth heavenward. This being man's prerogative, and emblematic of his high origin and destiny, how strange that human beings should, even in sport, much less as a serious pursuit, train themselves to assume an attitude which is precisely that of the apes, in the so called "Grecian bend," which, I am happy to see, is gradually disappearing from respectable society. The head is disfigured by a ponderous *chignon*, which is comparable to the filthy masses of hair long cultivated by some low African tribes; to balance this unnatural weight, the head and body are tilted forward; one bad bend demands another, so the knees are bent and the heels raised, and the latter are propped up by those instruments of torture and disfigurement, high-heeled boots. The total result is an attitude which is as completely that of the orang-outang as the human body is able to assume, but no ape has ever been known to adopt a "bustle" in order to call still further attention to those parts of the body which his organization has caused to project. If the theory of derivation be true, then the artificial Grecian bend of the fashionable nineteenth century is a "reversion" to the natural monkey bends of our ancient ape-like progenitors.

How we Walk.

In walking, the trunk and head are the *weight* to be carried; the legs have the *power*, and this power is exerted upon the feet, which form *fulcra* and *levers*, in connection with the floor or the earth; but we shall find that the body is not a dead weight, but elastic and alive, moving slightly in the direction needed to maintain the balance of the whole; so too, the legs are not merely *muscles*, they are also a considerable weight, and adapt themselves to the surface over which we are moving; and finally, although the feet are chiefly mechanical instruments, acted upon by muscles which arise higher up upon the legs, yet they have muscles of their own which strengthen the arch under the instep already described and give to all their movements a peculiar grace which is seen in no other creature; the apes have a much shorter heel, and the dactyls (toes) are so much longer and curved, that they cannot plant the whole sole flat upon the earth, but only the outer border; moreover, their primus (or great toe) is much shorter than ours and stands out from the side of the foot like a thumb, so that it cannot, like ours, receive the weight of the body and aid in the spring for the next step ; the bear's pes, it is true is "plantigrade," like that of man, but the heel is short, the primus is shorter than the other dactyls, and the whole bony structure is so unlike that of the human foot, that instead of rising at the heel and springing from the toes, it is raised altogether, and put down again with a "flop," which is very much like the ungainly step of the negro minstrels.

Much more might be said of the peculiar structure and action of the human foot, which is a most interesting and useful part of the body, although much less is thought of it than of the hand, it is generally concealed from view, and the toes are the only parts of the body which have been thrown into disuse and seriously injured by civilization ; we ridicule the Chinese for the distortion of their feet, yet our fashionable bootmakers are quite as guilty, since they abhor the natural form of the foot, and decide upon the proper shape of their wares with very little reference to the parts to be covered by them ; the narrow sole, the inbent great toe and the elevated heel, are not a whit less ridiculous and injurious than the compressed foreheads of the Flathead Indians.

A good general definition of walking has been already quoted. The body is allowed to fall forward upon one leg, the other leg swinging forward like a pendulum, and planted at some distance in advance, this process being repeated for every step, the "leg-pendulum" of a short man swings of course more rapidly than that of a tall one ; in the words of Dr. Holmes, "Commodore Nutt is to M. Bihin, in this respect, as a little, fast-ticking mantel clock is to an old fashioned, solemn-ticking, upright timepiece."

The same author makes the following statement : That a man is shorter while walking than while standing ; and as the explanation of this fact involves most of the things I have to say, I will endeavor to show why it is so.

But first, is it a *fact?* There is a time when we rise upon the foot, and when one would expect the height to be increased. In proof that Dr. Holmes is right, we have, first, the evidence of ladies, who say that a skirt which does not reach the ground while standing, may sweep the ground while walking ; and second, the experiment which I now try, of walking rapidly, with the eyes shut, under a rod which just touches the top of the head while standing under it ; in order that this experiment shall be satisfactory, however, the following conditions must be observed : The rod must be steady and horizontal ; the person walking under it should have no idea of its exact location, and should walk in a natural manner, neither "ducking" nor throwing the head back, as one is inclined to do when passing under any thing; a little brush, filled with paint and set into a cork pinned to the crown of a hat so as just to touch the rod while standing will never touch it while walking under if the above conditions are observed.

Granting the fact, how shall we account for it?

First, we must distinguish between the *length* of the body and its *height*.

The length of the body is the distance between two parallel but not necessarily horizontal planes, coinciding respectively with the two extremes of the body, the vertex and the soles. This length will be greater or lesser according to the state of the *respiratory organs*, as I show by experiment; if the short arm of a lever be placed upon the head while the lungs are empty, the other arm will fall as soon as a breath is taken in; in part, this explains why a wrathful man looks taller, since he is generally holding a full breath.

This length will also vary according to the *attitude* of the body; for the different segments of the spine (vertebræ) are separated by elastic cushions of fibro-cartilage, which are compressed by the body's weight while in the erect position, but extend themselves when we lie down. This also is easily shown by experiment: A rule is fastened to a board, and the difference in height of a man while standing up and while lying down upon it is at once indicated by a sliding piece, like that of a shoemaker's rule. This experiment is more striking if some weights are held in the hands while standing. The compression of the intervertebral cartilages accounts for the familiar fact, that we are shorter at night than in the morning; and also for the stunting of young persons who are overworked, or obliged to carry great weights. Finally, the length of the body as a *whole*, varies with the position of the head, trunk and legs, or that of the segments of the legs, as is easily shown by experiment: If we stand under the short arm of the lever already mentioned, any inclination of the head in any direction will allow the long arm to rise; so will any bending of the trunk itself, or of the trunk at the hips, or of the thighs at the knees; the same result follows when standing upon one leg, for then the opposite side of the body is unsupported and sinks a little, while the middle of the body swings toward the supported side, so that trunk and leg are not in a straight line, but form an open angle at the hip.

That the whole body must be shorter when any of its parts are bent upon each other can also be proved by geometry. A straight line measures the shortest distance between any two points; when the body is erect and the legs straight, it coincides with a straight line, but when it or any of its parts are deflected, then it departs from the straight line and becomes part of a curved and therefore *longer* line, and as a part is less than the whole, the body is then shorter than before.

So much for the *length* of the body; its *height* is the distance between two parallel *and horizontal* planes, coinciding as before, with the vertex and the soles; in other words, the height of the body is measured upon a *vertical* line, while the length may be measured by *any* line; and, moreover, the height may be varied without a change in length, as when the body is inclined as a whole in any direction, yet preserves its erect position so far as regards its different segments; this, of course, could only occur while the body is supported by a board or other unyielding surface, but it proves the theoretical distinction between length and height.

Practically, the height of the body is affected by whatever varies the length, so that we reach the following conclusion: A man is at his average height in the middle of the day with the lungs moderately distended, when standing erect with both feet flat upon the earth and the trunk and limbs in the same vertical plane; his height is greater in the morning, and after a full inspiration, and when the feet are extended upon the leg; his height is less at night, after a complete expiration, when out of the perpendicular, or when any two segments of the trunk, head or legs are flexed upon each other.

Now, the time of day and the state of the lungs have no direct connection with locomotion, so that in the endeavor to account for the decrease of height while walking, we have to consider only the deflections from the perpendicular straight line which may occur during locomotion.

The most constant of these is the forward inclination of the trunk from the hips, in order to allow the weight of the body to aid in overcoming the resistance offered by the air, just as a rod carried upon the finger must be inclined in order to prevent the air from carrying it backward.

This inclination of the trunk may be hardly noticeable, as in slow walking, but when the speed is increased the resistance of the air is much greater, and it has been found that in rapid walking the trunk inclines forward at an angle of fifteen to eighteen degrees.* Of

* Article "Motion," Cyclopedia of Anatomy and Physiology.

course it is possible to walk and even run with the trunk nearly erect, but in that case the resistance of the air must be overcome by muscular effort, just as a rod must be held very firmly in the hand in order to be carried forward in a vertical position.

As has been already shown, the forward inclination of the trunk, since it is a deflection of the whole body from a perpendicular straight line, tends to lessen the height while walking, other things being equal.

The second deflection from the perpendicular is the lateral inclination of the trunk from the hips during all parts of a step in which the body is supported by a single leg. The center of gravity of the trunk lies between the hips, and a line dropped from it must always come inside the points of support; while standing upon both feet, this line will come between them, but when supported wholly or in part upon one foot, the center of gravity must be so shifted as to be over that foot, the whole body swings over toward the side of the supporting leg; but in order to preserve the balance, the trunk is not kept in the same line with that leg but remains nearly erect, and so forms an open angle with the leg. According to the proposition already given, this must lessen the height at all parts of the step excepting when the body is equally supported upon both feet, that is, in every position excepting the "rest," and the "heel," which will presently be described.

The movements of the legs themselves during walking are much less simple and easy of description, as any one may learn for himself by trying to follow his own movements and to describe them. At any rate, I have found no satisfactory account of them in books, and am far from convinced that the one I shall now give is correct in all respects; for in order to explain the decrease of the height during walking, we must not only know how each leg moves by itself, but also observe the coincidence in the movements of the two legs; and every one knows how difficult it is to watch two people carefully at the same time.

There are two methods of studying the various positions assumed by the legs during locomotion; the first is by means of the "instantaneous photographs;" in the article already referred to, Dr. Holmes reproduces four such figures, showing several points very clearly, namely; the length of the stride in rapid walking, the planting of the heel of the advancing foot, and the great elevation of the other heel just before that foot leaves the ground. But excellent and well chosen as are these figures, they are insufficient for our purpose;

chiefly because the *same* foot cannot be traced in its progress from the beginning to the end of the step, and because the several figures do not agree in height and attitude. I selected fifteen figures or groups from several hundred such stereographs, and had them enlarged by photography upon a single card; they illustrate the points above mentioned, and also the rapidity with which one foot swings by the other, since in some cases the lower part of the swinging leg is nearly invisible. Still I found it impossible to so arrange these figures as to show all the subdivisions of a single step with the same foot.

The other plan adopted is as follows: Having first carefully practiced and studied the various movements which occur while walking, and ascertained which are the most easily recognized positions, I mounted a table, and, by aid of a supporting rod, assumed these positions, and remained in each of them long enough to allow the artist* to make these diagrams. To these positions I have given names for convenience of description and reference; but it should here be stated that it is quite possible that they have been christened already by some German authors of papers upon human locomotion in Müller's Archive für Anatomie, which I have not yet been able to read in detail.

The position of "rest" (fig. 3), is that in which both feet rest flat upon the earth, the one perhaps a little in advance of the other; we are then at our greatest normal height; and in my own case, this is thirteen-eighths of an inch greater than the least height reached in the course of the step. The next position is called "ready" (fig. 4), because the body is swinging off to the left so as to be supported chiefly by the left leg, and the knee is bent slightly in readiness for the succeeding movement; the deflection from the perpendicular in this position diminished my height three-eighths of an inch, so that it was only ten-eighths of an inch greater than the least height. The next position is taken when the body is swung still farther to the left, the right knee more bent and the foot just raised from the ground so as to swing clear in the next movement; in this "raise" position (fig. 5) the height is still further decreased by two-eighths of an inch, so that it is just an inch above the least height. In the next position (fig. 6) the body is allowed to fall forward, and a *spring* is at the same time given by the foot, the heel of which rises from the ground; but although this, other things being equal, would tend to increase the height, yet so decided is the "fall" that, in my own case, the height was diminished three-eighths of an

* Mr. George Le Baron Hartt, of Ithaca, who has also drawn these diagrams upon wood for the present publication.

inch; but as this "fall" or "spring" position is not a real "position," but a continuous movement of the whole body, the exact decrease in height will vary from its beginning to its close in the next position. In this (fig. 7), the heel of the advancing foot comes to the ground, while the heel is still further raised, so that the body rests upon the

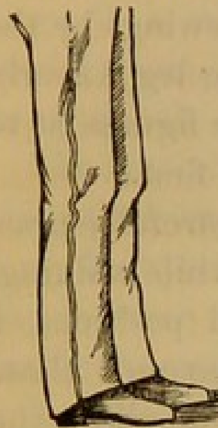

FIG. 3.
"Rest"—13-8.

FIG. 4.
"Ready"—10-8.

FIG. 5.
"Raise" or "Swing" —8-8.

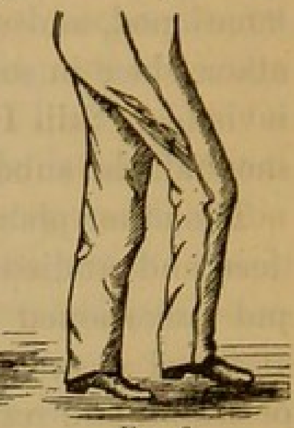

FIG. 6.
"Fall" and "Spring." —5-8.

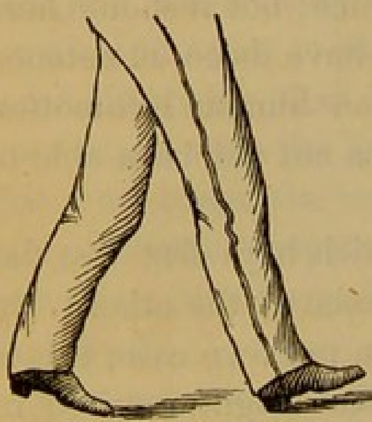

FIG. 7.
"Heel"—0.

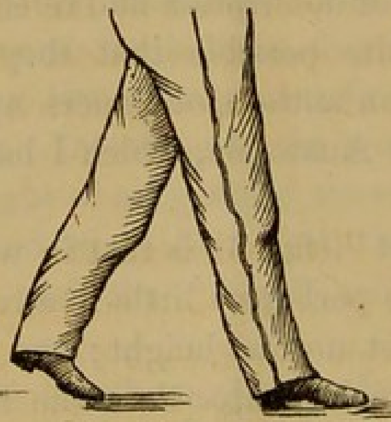

FIG. 8.
"Sole"—5-8.

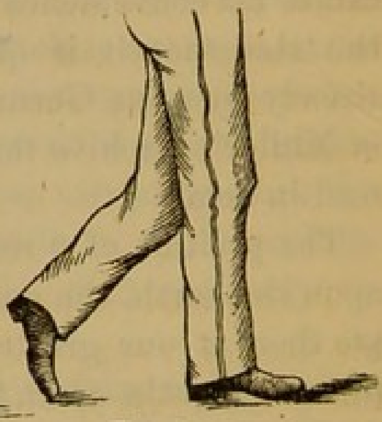

FIG. 9.
"Toe"—6-8.

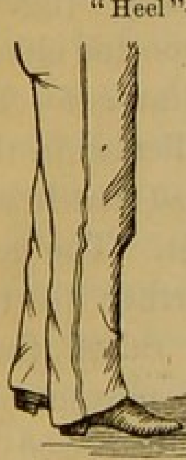

FIG. 10.
"Swing"—8-8.

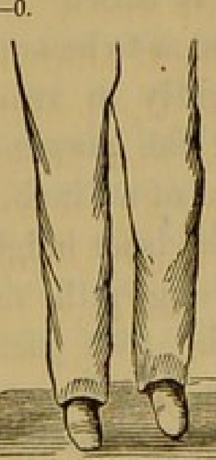

FIG. 11.
"Swing"—8-8.

FIG. 12.
"Fall" and "Spring" —5-8.

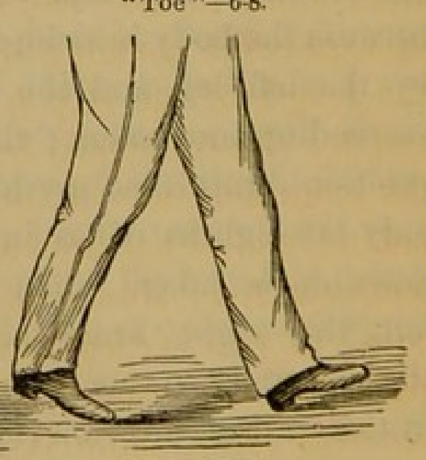

FIG. 13.
"Heel"—0.

heel of one foot and the toes of the other; and although the trunk is now nearly erect, and the elevation of the heel and toe tend to increase the height, yet the separation of the legs lowers the body another five-eighths of an inch, and the height is least (0) in this the "heel" position.

In the next, or "sole" position (fig. 8), the heel rises still further, and the body is carried forward by the continued spring from the foot, the sole comes flat to the ground, and the height is increased by five-eighths of an inch; it would be even more increased but for the commencing deflection of the trunk toward the right; in the next or "toe" position (fig. 9) the leg comes more nearly into a vertical plane above the foot, but inclined to the right, while the heel rises until the whole sole falls backward, and only the *toe* touches the ground; the height is here increased by one or two eighths of an inch, and in the next or "swing" position (figs. 10 and 11) it rises to eight-eighths or just an inch above the lowest point, this being, in fact, the same position as that already described as the "raise" or "swing" (fig. 5). If we mean to close the step here, the left foot is planted by the side of the right in the "ready" position, and thencomes the "rest," in which the greatest height in attained. But if another step is to be taken, then the swing is succeeded by the "fall" or "spring" from the right foot (fig. 12), and then comes the "heel" position, as before (fig. 13), the body being supported by the *left* heel and *right* toe.

The Gradigraph.

Taking now a piece of chalk and holding it steadily against the blackboard, I take a single step forward and stop at the "heel" position; the chalk has made a downward curve; continuing the step and coming to the "rest" position, the chalk makes a corresponding upward curve reaching the level from which it started; in this way, the length of the step is indicated both by the length of the curve and by the difference between the highest and lowest points. At the same time, as may be seen by observing a person walking, from behind, and as has been already proved by our experiments, the head oscillates from side to side in each step; but each lateral curve is equal to two vertical curves, because, during a single step with the right foot, for instance, the head has swung off to the right side and *remains there*, while it has not only sunk to its lowest point but risen again to the highest; so that half of a lateral curve, is equal to a whole vertical curve, and in a series of these, one lateral curve is equal to two vertical curves, as already said.

While making these experiments, it occurred to me that a simple instrument might be devised which should register the lateral and vertical curves at the same time in such a way as to enable us to compare and study them. After various trials, which I will not here enumerate, the "gradigraph," or "step recorder," became the instrument which will now be used.

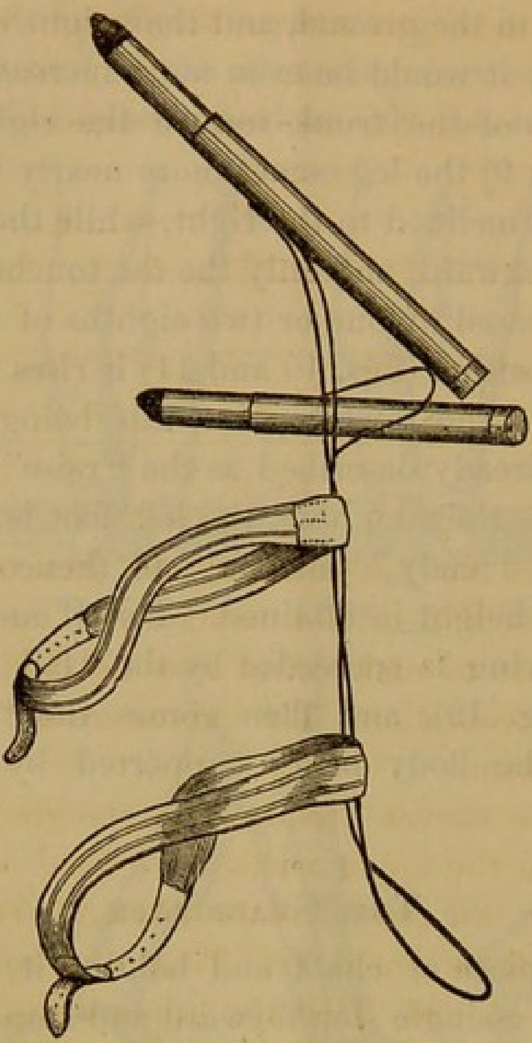

Fig. 14.
The "Gradigraph," or "Step Recorder," seen from the side.

It consists of two tin cylinders, one inch and a half in diameter, so attached to a frame of iron wire as to point forward at an angle of forty-five degrees, the upper one in a vertical, the lower one in a horizontal plane, and to the right. The lower and inner ends of the cylinders are closed; in each runs a hard wood piston upon a spiral spring. Each piston projects about four inches from its cylinder, and carries in its outer end a crayon of charcoal. For use, the frame is strapped firmly upon the back, so that the upper piston projects a few inches above the head, and the lateral piston a few inches beyond the right shoulder; the wearer then takes position beneath one board and at the side of another, so arranged that the crayons are in the center of the boards, and the upper piston is forced about two inches downward to enable the crayon to remain in contact with the upper board during the lowest position of the step; the wearer now steps forward in as natural a manner as possible, merely taking care to keep the lateral crayon in contact with the board. A series of vertical and lateral curves will be described, which, if faint, may be traced over with the charcoal. If the upper board is now let down so as to rest obliquely just above the lower board, these curves appear as follows:

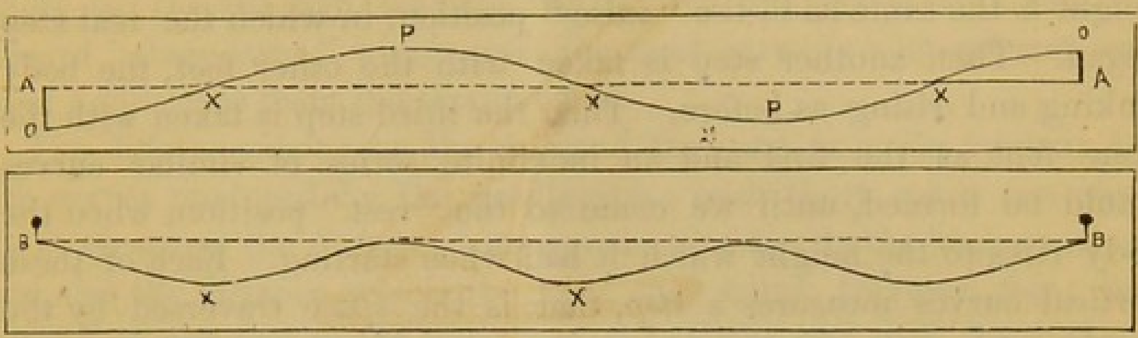

Fig. 15.

The above curves do not indicate the exact *amount* of either lateral or vertical oscillation; for, beyond the figures already given, I have not been able to make what may be called the quantitative analysis of human locomotion. The curves are somewhat exaggerated to facilitate comparison.

In comparing the curves produced by the gradigraph it must be borne in mind that the upper series are *lateral* while the lower are *vertical*. Although we cannot show them otherwise than upon the same surface, it will be noted, 1st. That each upper curve is equal to two lower curves. 2d. That the upper series are represented as lateral *oscillations* with respect to the dotted line A A, while the lower curves simply rise and fall with respect to the dotted line B B. 3d. That the extremes of departure of the upper curved line from the line A A coincide with the extreme elevations of the vertical line toward the line B B. 4th. That the points of intersection of the upper line with the line A A, coincide with the extreme depressions of the lower line from the line B B. 5th. That while each *entire* upper curve equals two lower curves, each lower curve coincides in length with so much of an upper curve as lies upon the same side of the line A A, so that X X is equal to Y Y. 6th. That at each end of each curved line is a short straight line at a right angle to the lines A A and B B.

Now, to state the same facts in connection with the movements of the body. The lower series represents the rise and fall of any part of the trunk, say the shoulder, from which the lateral barrel of the gradigraph projects. In the position of "rest" this point will have its greater elevation; but in preparing to take a step forward, the lateral swing of the body into the positions "ready" and "raise," causes this point to fall five-eighths of an inch (more or less). When the advancing foot has been planted and the position of "heel" is taken, the height is least; but then the body begins to rise upon the advanced foot until the "swing" position is reached, in which the height is the same as in the "raise" position, in which the real step began. Then another step is taken with the other foot, the body sinking and rising as before. Then the third step is taken with the same foot as the first and an indefinite series of similar curves would be formed, until we come to the "rest" position, when the body rises to the height which it had when starting. Each of these vertical curves measures a *step*, that is the space traversed by the trunk and head in passing from the "swing" position upon one foot to the same position upon the other; and this step is also the distance between the heel of one foot and the toe of the other in the "heel" position.

The upper series of curves represent the lateral oscillations of the head in respect to a line connecting with its positions when at *rest*. In preparing to take a step, the body swings off toward the side of the supporting leg, as shown in figs. 3, 4 and 11, and the head begins to advance, therefore, not from A, but from O; by the time the "heel" position is taken, with the advancing foot planted at a point under P, the head has moved back to the line A—A, but leaves it again and reaches P, while the body is advancing to the swing position in readiness for another step; then it again crosses the line A A at X, and describes a second curve, X—X; finally, having again reached the point O, if the position of "rest" is to be taken, the head comes back suddenly and without advancing to the point A.

Of course, the *length* of both lateral and vertical curves will depend upon the length of the step, and so will the *depth* of the *vertical* curves; but the degree of lateral oscillation of the head, as indicated by the upper series, depends not upon the length of the step directly, but upon the height of the individual, and also upon his width; for, in order to preserve the center of gravity over the point of support, of two men equal in *width*, the *taller* will oscillate the more; and of two men equal in *height*, the *wider* will oscillate the more. But there are also individual peculiarities of gait which may not depend upon either of the above conditions, and which would be merely indicated by a trial with the gradigraph.

This instrument is evidently capable of much improvement in detail, which I hope sometime to make, but I am convinced that even now it shows more clearly than has been heretofore, the relation of the lateral and vertical oscillations to each other, and the extent of each in the gaits of different persons; it may even be possible to give it such accuracy as to enable us to discriminate between the gaits of different nationalities as readily as we can now between those of the short and the tall man, between the natural, unaffected walk and the absurd "stage strut," which gives the most extensive lateral and vertical oscillations from the straight line.

The difference between the step and the pace is made evident by the curves produced by the gradigraph; each short curve is a *step*, for it measures the distance between the two feet in the heel position, and also the distance which the head and trunk traverse from the "rest" of one foot to the "rest" of the other; but each long curve measures a *pace*, or two steps, being the distance between the points where the same foot is raised and planted again; likewise the distance traversed by the head and trunk from the rest of one foot to the rest of the same foot, after two steps have been taken. If a man's step, then, is twenty-eight inches, his pace is fifty-six inches.

Besides the forward movement of the body in walking, and the lateral and vertical oscillations already described, there is a fourth movement, consisting of a partial revolution of the trunk upon its own axis during the "swing" position, when the trunk is supported by one leg; the whole trunk is faced a little to the opposite side; the shoulder and hip of the supporting side are thrown a little in advance of those of the opposite side, as becomes still more apparent when a pole is strapped across the shoulders; this partial revolution of the body probably occurs with all, during natural walking; although it is in part contradicted by the alternate swing of the arms, the left going forward with the right leg, and so generating a force in the opposite direction; with large persons it becomes more apparent; an exaggeration of this same movement, generally accompanies the "Grecian bend" already mentioned, and the "bustle" then receives a motion, which is aptly described by the German word "schwanzen," applicable properly, only to the waggle of the tails of monkeys and other beasts. If our comparisons seem odious, they are just, and even lack some of the features, which would yet more distinctly indicates the source of all these fashionable abominations among the *demi-monde*.

I have already mentioned the alternation of the swing of the arm, with that of the leg of the same side, or, in other words, the coincident forward swing of the left arm and the right leg, and of the right arm and the left leg; it is worth noting that this diagonal movement of the arms and legs, is precisely what occurs in the trotting of a quadruped, where the right hind leg and the left front leg are moved together forward and backward.

This brings us to a very curious matter, which is summed up by Dr. Holmes, as follows: One side of the body tends to *outwalk* the other side; that is, a person never goes in a perfectly straight line for any distance, but always turns to one side or the other, and at last describes a circle and returns to a point not far from where he started. Many such cases are on record, but I have not been able to learn to which side the turn was made; the Hon. John Stanton Gould informs me that he has frequently been lost in the woods, and thinks he turned without exception from *right to left;* that is, if he started to go due north he would deflect toward the west; he also mentioned a case of wandering in a circle by convicts who escaped from Clinton prison in this State, and referred me for further information to Mr. Ransom Cook, who was for a long time connected with the prison, and who has written me as follows respecting that case:

"The two convicts escaped from the prison about the middle of the day; they started north upon a run intending to go to Canada; they said they ran almost continually, until almost dark when they found themselves near the prison yard, about fifty rods further south than their starting point, while they had thought they were continually going north. They did not know in which direction they had turned, but it must have been quite abruptly to bring them back upon nearly the exact spot which they had left. I have been told by G. W. Beekwith, Esq., a lawyer of Pittsburgh, that it was a received opinion among hunters and woodsmen that lost persons traveled in a circle, turning to the left."

Now this is very interesting but not quite conclusive, and I would be very glad to have the experience of any persons who have been lost and have traveled in a circle; the experiment might even be tried by letting a man, unprejudiced, walk blindfold over a great plain covered with a light snow. I have tried an experiment upon a very small scale in a room forty feet long, trying to walk along a seam of the carpet with my eyes shut; in nine cases out of ten, I found my deflection to be to the *right;* and although I by no means regard such a trial as satisfactory, the result certainly accords with some facts already ascertained; for the greater propelling power of the right foot would cause the whole body to revolve more toward the right, and so turn the person toward the right, instead of the left side.

In this connection may be mentioned two facts which seem at first to contradict each other; the first is, that as a rule, the left leg is used for supporting the body, while the kick is delivered with the right, indicating the greater power of that foot; the other is that in marching, the time is marked by "left," "left," "left," spoken at the moment the left foot is swung forward to be planted in advance; and this would indicate that the left is the more important foot in walk ing, but not really; for although the left foot takes the step, the spring which determines the length and force of that step or movement, is given by the right, and it is said that in some cases a careful measurement of the steps shows that the impulse given by the right foot carries the left foot an inch or two farther than the right foot is in turn propelled by the left.

How we Run.

Between the walk and the run three differences will suggest themselves:

1. Running is faster than walking.
2. In running, the body is more inclined forward.
3. There is a greater spring in running.

But although these distinctions generally exist, they are not essential; for, (1.) You *may* walk much faster than you *may* run, although you *can* run the faster. (2.) You may walk with the body bent forward, and you may run with the body nearly erect. (3.) You may spring more, and so rise higher, in walking than in running.

There is, however, one difference between walking and running, which is less apparent, but is really the only essential difference. It is, that at every period of the step in walking some part of one or both feet is upon the ground; the body is always supported; but in running, there is a moment when the body is wholly unsupported, when both feet are off the ground.

Now let us note the movements in running. We may start from a standing position upon the flat of one or both feet; but after once starting, the heels rarely, if ever, touch the ground, and the ball of the foot both receives the weight and makes the spring. After starting, too, there seems to be only two real stages instead of five: one when the right foot is springing and the left is swinging forward; the other when the left is still in the air and the right also has left the earth; then the left comes down and makes the spring, while the right swings forward in its turn. The result is, that at one instant the body is supported by the ball of one foot, at the other instant by nothing at all; and this constitutes the main and essential difference between walking and running. Some figures of the appearance of the feet in walking and running I have given in "Bird, Beast and Fish," *Harper's Magazine* for November and December, 1869, and January and February, 1870. But the careful reader will observe that the descriptions are not the same as here given, and will be convinced that I am right in supposing still better ones will be given hereafter.

There are several other modes of human locomotion. We may hop upon one foot, or jump upon two; we may also leap upon two, but in leaping the two feet are not together as in jumping; and, finally, we may vault from one or both feet, aided by one or both hands. Springing, bounding and skipping are varieties of leaping, according to the relative height and length of the movement.

But our time has expired. I do not pretend to tell you all that is known, much less all that may some day be learned upon the subject of human locomotion; and although I hope to have made some points clearer than they were before, I am so little satisfied with my own explanation, that I am willing you should remain convinced of but one thing, that the most common actions of the body require careful attention; and that no branch of natural history, however minute, can ever be followed to the end; we may tire of it, and lose our hold of it; our successors may find in it more than we, but God alone knows all the fruit it may bear.