South Africa, presented by the Trustees of the South African Museum; two Schalow's Touracous (*Turacus schalowi*), four Cape Turtle Doves (*Turtur capicola*) from South Africa, presented by Mr. W. L. Sclater; a Vulturine Eagle (*Aquila verreauxi*) from South Africa, presented by the Rev. D. Kolbe; a Tawny Eagle (*Aquila noevioides*) from South Africa, presented by Mr. Claude Southey; a White-tailed Gnu (*Connochaetus gnu*, ♂) from South Africa, presented by Mr. C. D. Rudd; two Mandrills (*Cynocephalus mormon*, ♂ ♂), two White-collared Mangabeys (*Cercocebus collaris*, ♂ ♀), a Tantalus Monkey (*Cercopithecus tantalus*, ♂), a Lucan's Crested Eagle (*Lophotriorchis lucani*) from West Africa, a Spring-Bok (*Gazella euchore*, ♂) from South Africa, a White-tailed Ichneumon (*Herpestes albicauda*) from the Atbara River, a Yellow-headed Conure (*Conurus jendaya*) from South-east Brazil, four Lesser Pin-tailed Sand-Grouse (*Pterocles exustus*), a Black-headed Partridge (*Caccabis melanocephala*) from Arabia, deposited; a Roi Rhe-Bok (*Cervicapra fulvo-rufula*, ♂) from Maryland, Schombie Station, Cape Colony, a Gannet (*Sula bassana*), British, purchased.

## *OUR ASTRONOMICAL COLUMN.*

HOLMES' COMET (1899 *d*).

*Ephemeris for 12h. Greenwich Mean Time.*

| 1899. | | R.A. h. m. s. | | Decl. ° ′ ″ |
|---|---|---|---|---|
| Nov. 23 | ... | 2 13 55·17 | ... | +47 40 0·2 |
| 24 | ... | 13 6·67 | ... | 32 36·4 |
| 25 | ... | 12 20·16 | ... | 25 1·7 |
| 26 | ... | 11 35·67 | ... | 17 16·9 |
| 27 | ... | 10 53·25 | ... | 9 22·5 |
| 28 | ... | 10 12·94 | ... | 47 1 19·5 |
| 29 | ... | 9 34·75 | ... | 46 53 8·4 |
| 30 | ... | 2 8 58·72 | ... | +46 44 50·0 |

COMET GIACOBINI (1899 *e*).—Several observations of this comet having been obtained, Herr S. K. Winther continues his ephemeris in the *Astronomische Nachrichten* (Bd. 150, No. 3600):—

*Ephemeris for 12h. Berlin Mean Time.*

| 1899. | | R.A. h. m. s. | | Decl. ° ′ | | Br. |
|---|---|---|---|---|---|---|
| Nov. 23 | ... | 17 52 33 | ... | +10 17·6 | | |
| 24 | ... | 54 12 | ... | 10 34·0 | ... | 0·50 |
| 25 | ... | 55 52 | ... | 10 50·5 | | |
| 26 | ... | 57 32 | ... | 11 7·0 | | |
| 27 | ... | 17 59 12 | ... | 11 23 6 | | |
| 28 | ... | 18 0 52 | ... | 11 40·2 | ... | 0·48 |
| 29 | ... | 2 33 | ... | 11 56·9 | | |
| 30 | ... | 18 4 13 | ... | +12 13·7 | | |

During the week the comet passes from the northern part of Ophinchus into Hercules, about 6° east of α Ophinchi.

REFRACTION EFFECT OF COMET SWIFT (1899 I).—Prof. C. D. Perrine, during May and June 1899, made several attempts to determine if any appreciable refraction was caused by the body of Swift's comet on a ray of light passing through it, and contributes his conclusions to the *Astronomische Nachrichten* (Bd. 150, No. 3602). The observations were made with the 36-inch Lick refractor, and consisted of determining accurately the position angle and distance of two stars, (1) when one or both of them were seen enveloped in the mass of the comet; (2) when quite free from the cometary matter. The diameter of the head of the comet was computed to be about 174,000 miles, and the extent of matter traversed by the light from the stars about 163,000 miles. The greatest range of variation in the measured distance of the stars was 0″·26, which the author thinks in all probability accidental, as no systematic variation was detected; so that from these experiments the conclusion is that the mass of a comet causes no appreciable effect of refraction on light passing through it.

PREDOMINANCE OF SPIRAL NEBULÆ.—In the *Astronomische Nachrichten* (Bd. 150, No. 3601), Prof. J. E. Keeler describes the preliminary results of his inquiry into the structure of nebulæ. The discussion is based on photographs obtained with the Crossley reflector of the Lick Observatory, and the author finds that in addition to confirming the spiral structure of the nebulæ catalogued by the Earl of Rosse, so many others possess the same characteristic form that their being put in a special category loses its significance; in fact, any small compact nebula not showing evidence of spiral structure, appears exceptional. He finds gradations leading to the belief that the elongated spindle-shaped nebulæ of Herschel also really belong to this class. The author concludes by stating that if numerous exceptions prove that spirality in nebulæ is not an universal law, it may perhaps be regarded as the usual or normal accompaniment of contraction in cosmical masses, and any departure from it may be explained as the result of special conditions, tending to suspend or weaken causes which are generally in operation.

BULLETIN ASTRONOMIQUE.—The *Bulletin Astronomique* for November 1899 contains an illustrated article by M. Camille Flammarion on the "Eclipses of the Twentieth Century visible at Paris." Forty-three eclipses of the sun will be visible, two of them being total, and thirty-three presented in good positions for observation. The particulars of each are given, with a diagram showing maximum phase. The same author describes the observations of 339 Perseids made at Juvisy from 10–13 August 1899, with illustrations showing the plotted paths. The mean position of the radiant was RA = 3h. 3m.; Decl. + 56°.—M. Souleyre concludes his article on the "Distribution of rain on the earth's surface."—M. A. Benoit contributes a very interesting article on "Transneptunian planets," giving particulars respecting a proposed instrumental equipment for a systematic search for such bodies.

## *THE FITTING OF THE CYCLE TO ITS RIDER.*[1]

THE present time is opportune to notice some points in cycle riding which have received our attention during the last three years. Every intelligent rider of a cycle must have at some time compared his powers as a human motor with the motors that drive the motor-cars which he now so frequently meets in the streets. He naturally wishes to study the question of most efficient propulsion, including that of his own mechanical efficiency as a motor driving his cycle. The design of the modern cycle was so far developed by 1896 that a standard type then became the rule, most cycles having a 45-inch wheel base, two wheels of equal diameter 28 inches, cranks 6½ inches long, and a ratio of gear varying between 59 to 80 inches, the sole difference made between cycles intended for tall riders and those for short ones consisting in varying the height of the frame. In 1896 the writers, being urged thereto by Mr. Otto Blathy, the well-known engineer of Budapesth, had their attention called to the necessity of varying the crank length to suit the varying length of leg of the rider. A series of experiments was carried out for cranks up to 9½ inches long, and the results obtained were very remarkable. It may now be taken as admitted that a very large proportion of the riders who have tried cranks of increased length have found great benefit from their use, but although they feel strongly how tangible these advantages are, some difficulty has been felt in satisfactorily explaining them.

All that has been written on cycle riding in the past has been confined to the style of riding which has been gradually elaborated on cycles fitted with the standard 6¼-inch to 6½-inch cranks, but this is little or no assistance to us when we attempt to investigate the subject through wider limits of muscular movement.

When mechanical engineers measure the efficiency of any form of mechanical motor they confine themselves generally to the consideration of the fuel that it consumes, but do not, as a rule, when considering its efficiency, take into consideration the cost of keeping it in repair, or include with it the cost of feeding and maintaining the driver; but the food which is the fuel of the cycle rider has not only to perform the same duties as the fuel of the mechanical motor, but has in addition to supply the nerve waste and repair the muscle waste which answers to the repairs to the mechanical motor, and from the same supply to maintain the brain power of the driver. The food energy of the cyclist has, therefore, to be distributed through three distinct channels: the first in importance is that which is required

[1] Abstract of paper read before the Cycle Engineers Institute at Birmingham, by R. E. Crompton and C. Crompton.

to repair brain waste, and which we hereafter call "Brain Waste"; second, that required to supply the nerve action, which energises the muscles when ordered to do so by the brain, and which we hereafter call "Nerve Waste"; and third, that for the upkeep of the muscles themselves, and which we hereafter call "Muscular Waste." Hitherto writers have, we believe, given too much prominence to the last-named of these. We think that, instead of being the most important of all and taking the largest share of food, it is probably the least important of the three. Dr. E. Turner has shown a method of estimating, with considerable scientific accuracy, the proportions of the food supply required by the above three sources of waste. He has noticed that the proportions of uric and phosphoric acids present in the human urine after exertion give the measure of the brain and nerve wastes relatively to the urea present, which is a measure of the muscle waste. A long series of experiments have made us feel reasonably certain that the nerve waste is practically proportional to the number of times that the nerve centres energise the muscle in order that it may make a stroke; in other words that the nerve waste is proportional to the number of revolutions of the crank shaft of the cycle, and it is doubtless this fact that has led to the craving for high gears, which allow of a reduced number of crank revolutions, as riders have found that by pedal during the entire revolution of the crank shaft in order to drive his cycle at the required speed. We measure the total resistance or pull of the cycle on the road in lbs., and call it total resistance expressed by our symbol "R," the power exerted by the cyclist, that is, the rate of doing work in foot pounds per minute by the symbol "P," and the work done in foot pounds per hour by the symbol "W." So long as the crank lengths are kept constant, or nearly so, the term geared to 60 or 70, as the case may be, give a sufficiently accurate idea of how far the pedal pressure "F" is influenced by the ratio of revolutions of the crank shaft to that of the driving wheel, but immediately the crank length is varied this term gear leads to confusion. We think a better term is multiple, which we denote by the symbol "M." "M" is the figure by which the angular speed of the feet or pedal is to be multiplied in order to get the lineal speed of the cycle moving along the road, consequently R multiplied by M gives F. We have prepared several tables which give the value of "R" for speeds varying from 5 to 20 miles an hour. It will be seen that "R" consists of three parts, $r1$, $r2$, and $r3$. $r1$ is the mechanical friction of the cycle, $r2$ is the road rolling and tyre resistance; these two first are functions of the weight of the machine and its rider, $r3$, the most important of all, is that due to air resistance. In a second table we have the

TABLE I.—*Giving Values of R for a Rider and Cycle weighing* 190 *lbs. at Speeds from* 5 *to* 20 *miles an hour.*

| V = miles per hour | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind pressure in lbs. per sq. ft. = $\cdot 00241 V^2$ | ·0602 | ·0867 | ·118 | ·154 | ·195 | ·241 | ·291 | ·347 | ·407 | ·472 | ·542 | ·616 | ·696 | ·780 | ·870 | ·964 |
| $R^3 = \cdot 00241 V^2 \times 5 \cdot 5$ sq. ft. when area is 5·5 sq. ft. | ·353 | ·48 | ·653 | ·85 | 1·08 | 1·33 | 1·64 | 1·92 | 2·25 | 2·61 | 3·00 | 3·41 | 3·85 | 4·32 | 4·81 | 5·33 |
| $R^1 + R^2 = \cdot 0008\ WV^{\frac{2}{3}}$ when W = 190 ... | ·94 | 1·07 | 1·2 | 1·3 | 1·4 | 1·52 | 1·61 | 1·72 | 1·82 | 1·9 | 1·98 | 2·10 | 2·16 | 2·25 | 2·3 | 2·4 |
| $R_1\ R_2\ R_3 = R$ ... | 1·293 | 1·55 | 1·853 | 2·15 | 2·48 | 2·85 | 3·25 | 3·64 | 4·07 | 4·51 | 4·98 | 5·51 | 6·01 | 6·57 | 7·11 | 7·73 |

TABLE II.—*Giving Values of F for a Rider and Cycle weighing* 190 *lbs. at Speeds from* 5 *to* 20 *miles an hour.*

| Miles per hour = V | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $M = 4\frac{1}{2}$ ... ... ... | 5·82 | 6·95 | 8·32 | 9·65 | 11·18 | 12·8 | 14·6 | 16·4 | 18·3 | 20·3 | 22·4 | 24·8 | 27·0 | 29·5 | 31·9 | 34·8 |
| $M = 5$ ... ... ... | 6·45 | 7·75 | 9·25 | 10·7 | 12·4 | 14·25 | 16·23 | 18·2 | 20·3 | 22·5 | 24·8 | 27·5 | 30·0 | 32·7 | 35·5 | 38·6 |
| $M = 5\frac{1}{2}$ ... ... ... | 7·1 | 8·5 | 10·2 | 11·8 | 13·6 | 15·65 | 17·85 | 10·0 | 22·4 | 24·75 | 27·3 | 30·3 | 33·1 | 36·1 | 39·2 | 42·5 |
| $M = 6$ ... ... ... | 7·75 | 9·3 | 11·1 | 12·9 | 14·9 | 17·05 | 19·5 | 21·8 | 24·5 | 27·0 | 29·8 | 33·1 | 36·2 | 39·4 | 42·9 | 46·4 |

reducing the number of crank revolutions they can economise their nerve waste so as to leave a greater reserve of food energy to supply brain and muscular waste. Our attention was directed to this at a very early stage in our experiments; but we found that a limit was soon reached to the raising of the gear, as if the crank length is kept constant the crank pressure necessary to drive the cycle increases just as the gear is increased, so that a strain is brought on the muscles at times of facing high winds or climbing steep hills, which is greater than the muscles can stand without muscular soreness setting in; in fact, the limit of strain is surpassed, which it will be convenient to call the "elastic limit" of the muscles, and whenever this "elastic limit" is passed for more than a few minutes the muscle is temporarily weakened for the remainder of the day's run; in fact, the repair of that muscle cannot be made until the rider rests and sleeps as well.

We have adopted this term "Elastic Limit" of the muscles because it corresponds very closely to a term well known to mechanical engineers when used to express the extent to which metals may be strained or stretched without taking permanent set; so long as they are subjected to strains within this limit no permanent injury is done to the metal, whereas if it is passed the structure of the metal is altered and becomes weaker and liable to fracture. This process of being strained, even to a small extent above the elastic limit, has been sometimes called the fatigue of metals, and is somewhat analogous to the fatigue of muscles strained above their elastic limit.

We use the term "Pedal Pressure" and symbol "F" to express the pressure in lbs. which the rider must apply at the value of F worked out for various multiples, and in a third table we give the value of F under maximum conditions of hill climbing at a speed of 8 miles an hour. From

TABLE III.—*Values of F in lbs. on Various Hills with Different Values of M at* 8 *miles an hour.*

| Hill of | 1 in 30 | 1 in 25 | 1 in 20 | 1 in 15 | 1 in 10 |
|---|---|---|---|---|---|
| $M = 4\frac{1}{2}$ | 38·160 | 43·875 | 52·425 | 66·645 | 95·175 |
| $M = 5$ | 42·40 | 48·75 | 58·25 | 74·05 | 105·75 |
| $M = 5\frac{1}{2}$ | 46·640 | 53·625 | 64·075 | 81·455 | 116·325 |
| $M = 6$ | 50·88 | 58·50 | 69·90 | 88·86 | 126·90 |

these tables we are able to show that we have to deal with values of F varying from 18 lbs. to 130 lbs. It will be seen that the F required by an average rider using a multiple of 5 when he is maintaining a speed of 12 miles an hour on a calm day will vary between 18 lbs. and a maximum of 106 lbs. when he is climbing hills of 1 in 10 at a reduced speed of 8 miles an hour. These figures are representative as average conditions of the forces which have to be exerted by riders, although it is needless to say that far greater values of F are reached by riders when racing or in hill-climbing competitions.

We have endeavoured to give some approximate value of the elastic limit of muscles, and have made extended experiments to settle this point. In the case of one of the writers, the elastic limit of the quadriceps cruris at the point where soreness is usually felt, *i.e.* just above the knee, appears to be that corresponding to an F of 120 lbs., so that in this case with a multiple of 5, whether the arrangement be $6\frac{1}{2}$-inch cranks, 65 gear, or $9\frac{1}{2}$-inch cranks, 95 gear, a gradient of 1 in 10 can be ridden, and it is probable that this limit can be reached for three or four minutes without causing the muscular soreness. This of course varies greatly with the physical condition of the rider, but it is probable that this elastic limit is a function of the cross section of the muscle, and that the above value may be taken as an average one for men of average physique; with women it is probably somewhat less. It appears certain that the value of the elastic limit is a most important determining factor in designing a cycle to enable a rider to develop his physical powers when cycle riding in the most efficient manner. Once we determine it we can fix on the multiple M, and then, as we desire to keep down the nerve waste by reducing the crank revolutions for a given road speed, we can only do this, as M is a fixed quantity, by increasing the crank length. To what extent can this be done to give the best possible efficiency? The rider's thigh bones and the muscles that work them up and down may be looked upon as levers working on the hip joint as a fixed point, the outer ends being connected to the pedal by the shank bones, ankle joint and foot acting as a rather complicated connecting rod. The effective length of the thigh bone of riders varies between 15 inches for short men and 23 inches for tall men. The length of the standard $6\frac{1}{2}$-inch cranks is therefore 43 per cent. of the length of the thigh bone on short riders, but only 28 per cent. of its length in tall men. In the case of the writers it is about 35 per cent. It was necessary to determine this proportion of the crank length to the thigh-bone length.

Our experiments, extending over three years, show that although we have gradually increased the crank length from $6\frac{1}{2}$ inches to $9\frac{1}{2}$ inches, in other words, from 35 per cent. up to 53 per cent. of the effective length of the thigh bone, we have not yet passed the point of greatest efficiency. Our proposals have of course been severely criticised, mainly by those who have not tried the system, and the following objections have been urged against increased crank length.

(1) Causing loss of power when hill climbing, or when riding against the wind, in fact at any time when the F required is considerable, and that this loss of power is caused by the excessive bending of the knee joint, which in its turn causes knee soreness.

(2) Militates against proper ankle action.

(3) Causing saddle soreness, bad steering, and other troubles.

(4) Causing extra strains on the parts and frame of the cycle.

Dealing with these questions in the above order, we have shown that the main object of increasing the crank length is to reduce the number of revolutions at a given road speed without increasing the value of F, and as it is practically certain that the knee soreness complained of entirely depends on this value of F not being exceeded, the only other way in which knee soreness could be produced is by excessive knee flexure. There are two ways in which this question of knee flexure may be considered. It has been said that when the knee is bent beyond a certain angle the muscles act at a disadvantage, and again that the extra flexure of the joints is the cause of the soreness which riders complain of, and that a rider having an 18-inch thigh bone can actually exert a greater pedal force at the half-stroke of $6\frac{1}{2}$-inch cranks with its corresponding knee angle, than he can with 9 inch cranks and the correspondingly increased angle. We have, however, settled this question by careful experiments made in a testing machine, and we have shown that the knee angle at which the maximum pushing strain can be exerted is that which corresponds to a crank length of $18\frac{3}{4}$ inches; in other words, that the maximum force of the leg is obtained with a knee flexure far in excess of that required for any possible crank length that could be used on a cycle, so that this question of loss of power from excessive knee flexure is completely disposed of. Fig. 1 shows these results plotted on a curve.

TABLE IV.

| Distance between hip-joint and ball of foot in inches | Angle at knee between shank and thigh | Maximum push in lbs. |
|---|---|---|
| | ° ′ | |
| 22 | 75 30 | 325 |
| 23 | 79 36 | 370 |
| 24 | 83 31 | 390 |
| $24\frac{1}{2}$ | 86 0 | 412 |
| 25 | 87 44 | 408 |
| 26 | 92 46 | 385 |
| 27 | 97 32 | 362 |
| 28 | 102 32 | 325 |

What writers mistake for knee soreness caused by excessive flexure is really due to the following cause. Any muscle which is constantly used throughout only a part of its stroke becomes developed and hardened into a condition which Sandow calls "a muscle-bound condition." It becomes shorter as it is never properly stretched out, the tendons which secure it also become shortened, and if this condition is not speedily remedied it becomes permanent. In the hard riding short crank cyclist, this applies to the quadriceps cruris, it being only called upon to work through a part of its stroke. When such a cyclist uses long cranks for the first time, he finds himself unable to properly flex his knee joints on account of this shortening of the quadriceps. The effort of stretching the muscle out to its full stroke causes the knee soreness complained of. There can be no question, however, that long crank riders benefit greatly by the extra knee flexure, compelled by the long cranks, and that this greatly increases their bodily activity and enables them to excel in exercises, such as running, walking, hill climbing and jumping, all of which require flexibility of the knee joint. Sandow points out that the best way to prevent the muscle-bound condition is to work the muscles in pairs throughout their full stroke; consequently, if we desire to develop the quadriceps cruris in a perfect manner to the full length of its stroke, we must also develop the muscles which form the pair to it on the underside of the thigh, *i.e.* the biceps cruris. It occurred to us, therefore, at an early period, that we ought to train these muscles to do their share of the work of propelling the cycle, hence arose what we call the pull stroke. Cyclists who use toe clips, or those who notch the soles of their cycling shoes, so as to get a better grip of their pedals, can use this pull stroke to a small extent; that is to say, they can claw or pull the pedal round

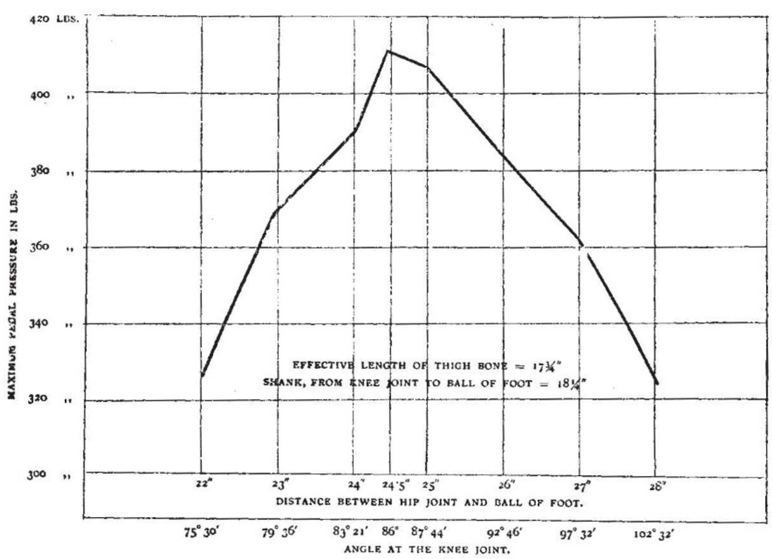



FIG. 1.—Curve showing relation between knee angle and maximum thrust on pedal.

during the lower portion of its circular path; but unless special devices are provided to enable them to draw the pedal upwards throughout a much larger arc, they cannot make use of the pulling muscles in a satisfactory manner. In order to do this we have bent our pedal plates slightly forward, as shown on Fig. 2, and we have prepared shoe plates of a form which enable them to hook into the back plate of the pedal.

It will be seen that our pulling device differs essentially from toe clips, which do not enable the upward pull being made unless the toe is pointing downwards. We find that this militates against good ankling action, and has a tendency to induce cramp in the calf muscles; on the contrary with our pulling device, the calf muscles may be quite inert during the upward stroke, the shank acting merely as a connecting rod in tension. It will be seen that the pull stroke enables us to reduce

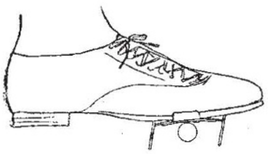


FIG. 2.

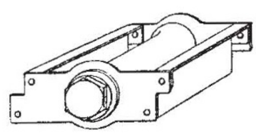


FIG. 3.—Crompton patent pedal.

the minimum pressure on the downward stroke, which is necessary to produce the average pressure F. Our experience of this subject is that it takes a long time to teach these muscles, which are seldom used except by running men, to take up their share of the work of cycle propulsion, and those who begin to use the pull stroke will find that, although it does greatly reduce the pushing strain made by the upper thigh muscles in hill climbing, yet that the thought and attention required to apply it under ordinary conditions of riding is so considerable that they do not persevere in practising it. It is our opinion that it is well worth while for a rider to cultivate the pull stroke. The pulling muscles are large and powerful, their elastic limit is high, it is not easy to overstrain them, and the extra brain

decreased, the force required to do this not coming from the muscles which move his leg, but from the calf muscles, which take a purchase, not against the saddle, as would be the case if he did not use ankle action, but against the pedal itself, so that the kinetic energy which is taken out of the leg in stopping its descending weight is usefully employed in propelling the cycle, and thus there is a great saving of energy by good ankle action.

If we take curve Fig. 4, the vertical lines of which represent velocity, the velocity downwards being represented by the vertical lines below the base line A B, and the velocities upward by the vertical line above it; if also we take the horizontal line to represent time when travelling with 60 gear and 6-inch cranks at 10·71 miles an hour, M being 5, a complete revolution is made in one second, and the upward and downward velocity of the leg at any moment is shown by the curve. Now rate of acceleration is change of velocity at a given time, and therefore the acceleration at any point is represented by change of velocity in a given time at that point. Suppose the acceleration to remain the same throughout that time as it is at the point P, the curve would describe a tangent to that curve at the point P and the acceleration—that is, the change of velocity divided by the time—would equal the tangent of the angle formed by the tangent of the curve with the base line.

You will notice that up to 90 degrees the tangent increases as the angle increases, therefore the steeper the curve at any point the greater is the acceleration at that point, and the greater the acceleration the greater the rate at which kinetic energy has to be taken out of the leg, and therefore the greater necessity for ankling. If, however, when riding at the same speed we use 9-inch cranks with 90 gear M is still 5, but the curve takes the form of the black line. You will see that the curve is obviously of the same relative shape as the red curve, but it is drawn out lengthways in the proportion of 6 to 9, and therefore the angles which the curve makes with the base line at any point is less than the angle which the red curve makes at a corresponding point. The tangents of the angle of steepness vary as 6 to 9, and the rate at which acceleration is reduced is also as 9 to 6, so that the necessity for careful ankling is in this case reduced in the same proportion, in other words, for equal

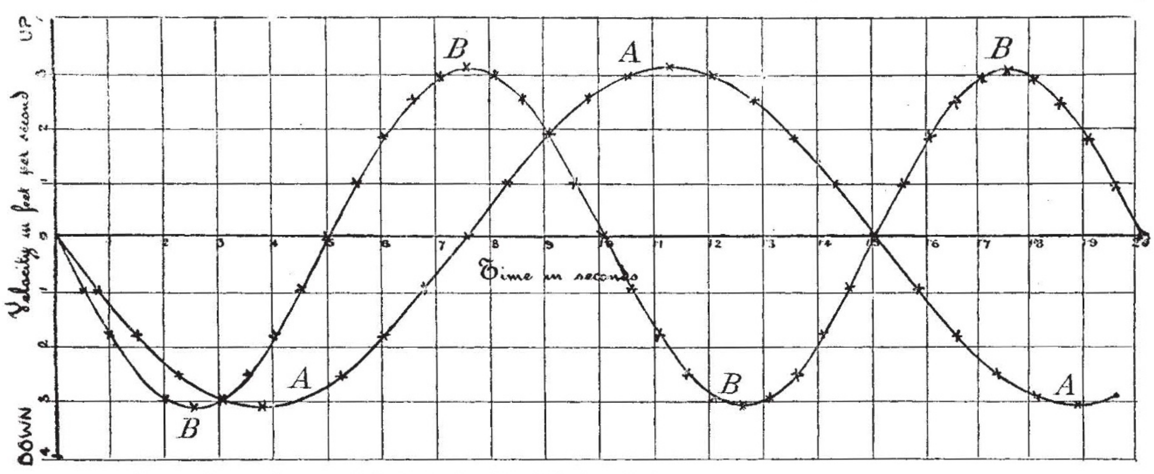



FIG. 4.—Curve B shows vertical velocity of pedal of 6 inch crank, 60 gear } Both at speeds of 10·71 miles per hour.
„ A „ „ „ 9 „ „ 90 „

waste that is required during the process of teaching these muscles is soon found to be reduced, as by practice these muscles automatically take up their share of the work.

It has been said that increased crank length militates against proper ankle action. The use of ankle action is not generally understood. The moving portion of a man's leg has considerable weight, when it is at the top of the stroke it possesses potential energy which is changed into kinetic energy as the leg descends, when it gets at the bottom of the stroke it stops going downwards and commences to rise, and the kinetic energy due to the downward movement of the leg has to be given up. What becomes of it? If the stopping of the leg is done by the same muscles which lift the leg there is a considerable waste of power, but if towards the lower end of the downward stroke the man begins to flex his calf muscles the velocity of his leg is gradually

efficiency long cranks do not require such careful ankling as short ones; although as more time is given in which to carry out such ankling, it is easier for the average rider to acquire it to a sufficient extent.

It is unnecessary to deal at any length with the question of saddle soreness. We cannot find that lengthened cranks have made any notable difference in this respect. Those who were liable to soreness with short cranks have not had this liability increased, but rather decreased by the new system. The position of the saddle has of course to be carefully attended to in riding with the lengthened cranks. As to the bad steering, this is an imaginary fault. We find that a well-designed machine will steer just as well, hands off, with long cranks as with short ones. It is true that the long cranks do introduce some extra strains into the cycle. The cranks themselves have to be carefully designed and made of special material. The use of nickel steel has enabled us to make the long cranks of ample strength, although they weigh very little more than short ones. The strains introduced into the frame are mainly those due to chain pressure, and are not influenced by crank length but entirely by the speed of the chain. The speed of the chain can be increased by enlarging both the sprocket and back pinion wheels. Summarising our results it appears—

(1) That when we talk of designing the cycle to suit any individual rider, so as to develop his powers as a motor to the greatest extent, we have first to consider how we can best economise his nerve waste by enabling him to reduce the number of revolutions and increase the stroke through which his legs can travel. Our experiments have shown us that these conditions are best fulfilled in the great majority of cases by giving to the rider a length of crank equal to half the length of his thigh bone.

(2) That the value of M the multiple, in other words the gear, is then to be determined by the maximum strains which his muscles will stand, and we believe in most cases this corresponds to a pedal pressure F not exceeding 100 lbs. for weak individuals up to 140 lbs. for strong ones.

(3) That the crank length determines the shape of the frame and the length of the wheel base, and that the extra long wheel base necessitated by the long cranks renders the cycle pleasanter to ride and does not materially increase its weight.

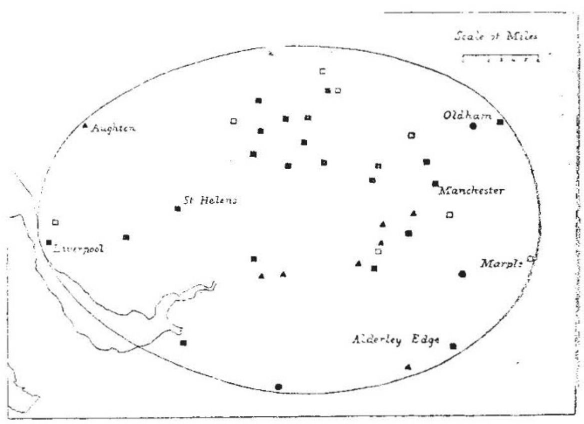
(4) That considering how important it is to reduce the number of crank revolutions in order to economise nerve waste, the cultivation of the pull stroke enables a greater average F to be obtained without straining the muscles beyond their elastic limit, and, consequently, allows of a higher multiple M and a correspondingly reduced number of revolutions. Out of a number of carefully made test runs we have selected the following as representative of the increased efficiency which we have obtained from the use of the lengthened cranks. The elder of us, aged 54, height 5 feet 10 inches, thigh bone 18-inch shank, from knee to ball of foot 21 inches, made a trial in the summer of 1896 with a cycle having $6\frac{1}{2}$-inch cranks, geared to $99\frac{1}{2}$. The total weight of rider and cycle was then 195 lbs., and the surface exposed to the air, including cycle, was $5\frac{1}{2}$ square feet. The maximum distance that could be travelled on a good road with an average wind was 78 miles in ten hours, including rests, or in an actual riding time of $7\frac{1}{4}$ hours. The average foot pounds per minute in this case was 2917. In September 1898 R. E. Crompton made a test on a cycle having cranks 9·1 inches long, geared to 102. The weight of the cycle and rider was, as in the former trial, made up to 195 lbs. The test run was from Kensington Court, London, to Romsey in the New Forest and back; total distance 156 miles, total time 13 hours 28 minutes, riding time 10 hours 54 minutes. The bodily fatigue on this day was no greater than on the 78-mile run in 1896. In this ride the average foot pounds per minute throughout the day was 6650, so that whereas with the old system of short cranks in 1896, R. E. Crompton was able to maintain P at 2917 for $7\frac{1}{4}$ hours, with the new system in 1898 he was able to maintain 6650 for 10 hours 54 minutes; in other words, from a given amount of food or, what is the same thing, a given amount of bodily fatigue, R. E. Crompton was in 1898, on the long-crank machine, able to do three times as much work as he did on the short-crank machine in 1896. Many other similar runs have been made, and other long-crank riders can produce equally satisfactory results.

The theory we have formed as to the nature of bodily fatigue induced by cycle riding, in which we have endeavoured to show the extreme importance of the part played by the brain and nerve systems, and that probably the major portion of the energy of the human body considered as a motor passes through the brain and nerve tissues to energise the muscles, is a matter which merits the careful attention of physiologists. Writers on this subject have hitherto considered the human or animal motor as a heat engine, all the useful energy being obtained by corresponding chemical work done on the muscles. We believe that the greater part of the energy-yielding processes goes on within the brain itself or in the nervous system directly connected with the brain. Many facts observed by cyclists and other athletes when carrying out feats of endurance show that brain and nerve nourishment is to be aimed at rather than the repair of muscle waste, and that certain foods and drinks have to be avoided on account of their action in producing temporary slackness; in fact, on account of their preventing the brain from effectively energising the muscles.

## NOTE ON THE DISTANCES TO WHICH EXPLOSIONS ARE FELT AND HEARD.

ST. HELENS being situated in a thickly populated district, the disaster at Messrs. Kurtz's works (belonging to the United Alkali Company) seemed to offer a good opportunity for determining how far a great explosion may be felt and heard. Isolated observations, as will be seen below, have been made on other occasions; but, to feel confidence in the results, we require a fairly continuous series of records extending from near the centre of disturbance to the boundary of the affected area. I therefore wrote letters to all the more important newspapers in the south of Lancashire and north of Cheshire, in request of observations either of the sound or of the movement of windows by the air-waves. In reply to them, I received more than fifty accounts, which, in addition to several which appeared in the local press, gave a total of 61 records from 47 different places.

The immediate cause of the explosion was the firing of one of the vessels used in crystallising the chlorate of potash, the vessels being made of wood lined with lead. It is computed that eighty tons of chlorate exploded. The whole of Messrs. Kurtz's buildings were razed to the ground, and nine out of ten great vitriol chambers on the other side of an adjoining road were destroyed. Within a few hundred yards of the chemical works there are many streets of workmen's cottages; the doors, windows, chimney-stacks of whole rows were dismantled, and, in some cases, the roofs fell in. Within a radius of a mile or so, hardly a window seems to have escaped;[1] but according




to one of my correspondents, who was in the north-west of the town, the damage to windows around him was comparatively slight.

On the accompanying map are shown all the places from which records of the explosion were obtained. A small square denotes a place where the air-wave was strong enough to make windows and doors rattle; if the square is filled in, the sound was also heard. Places where the observation of the sound only is recorded are represented by a circle if the observer was out of doors at the time, and by a triangle if he was inside, or probably inside, a house. A perceptible tremor of the ground, strong enough to be mistaken for an earthquake, was felt at some distance from St. Helens, but how far cannot be definitely ascertained.

It will be seen that the area over which the sound was heard is practically the same as that in which the air-wave was strong enough to make windows rattle. The bounding curve is elliptical in form, $39\frac{1}{2}$ miles in length from east to west, $27\frac{1}{4}$ miles in breadth, and includes an area of about 850 square miles. St. Helens lies close to the longer axis of the curve and nine miles to the west of the centre. Towards the east, the sound was heard at Alderley Edge ($24\frac{1}{2}$ miles from St. Helens) and at Oldham (27 miles). Windows were observed to rattle at Alderley Edge and also at Marple (28 miles). To the west of St. Helens the sound was heard at Liverpool (10 miles) and Aughton (10 miles). I have tried in vain to ascertain the direction of the wind at the time of the explosion at different places

[1] The above particulars are obtained from the account given in the *Manchester Guardian* for May 13.