experiments before the year 1851 with different coals suitable for the Navy. These trials were conducted near London, under a small marine boiler at atmospheric pressure.

(3) At the English Government dockyards, various interesting experiments have been made under small marine boilers, and the results published in Blue-books.

(4) Messrs. Armstrong, Longridge, and Richardson published in 1858 an account of some valuable experiments they had made with the steam-coals of the Hartley district of Northumberland, under a small marine boiler, for the Local Steam Colliery Association.

(5) At Wigan many excellent experiments were made by Messrs. Richardson and Fletcher about 1867, to test the value of Lancashire and Cheshire steam-coals for use in marine boilers. The water was evaporated under atmospheric pressure from a small marine boiler. This station was afterwards abolished.

In none of the above do the gases of combustion appear to have been analyzed.

(6) A fuel-testing station was worked at Dantzig in 1863.

(7) An important station was opened at Brieg, on the Oder, by the colliery-owners of Lower Silesia in April 1878, with the primary object of testing the value as fuel of the important coal-seams of that province. After working with the most satisfactory results for two years, and establishing the superiority of the Lower Silesian coal, the experiments terminated in 1880. The testing boilers had each 40 square metres of heating surface. Gases and coals were analyzed.

*Existing Continental Stations.*—(8) The Imperial Naval Administration Coal-testing Station at Wilhelmshaven, Germany, was established in 1877.

(9) Dr. Bunte's coal-testing station, erected at Munich about 1878, particulars of which have been published in the Proceedings of the Institution of Civil Engineers, vol. lxxiii. Here some hundreds of trials have been reported on and published; much valuable work has been done, and many fuels tested, including coals of the Ruhr valley, Saar basin, Saxon and Bohemian coal-fields, and those of Silesia and Upper Bavaria. The boiler of the station has about 450 square feet of heating surface. The gases and coals are analyzed, and all particulars carefully noted. It is one of the most complete stations I have seen.

(10) In Belgium, near Brussels, there is a Government station for testing fuels, under the administration of the Belgium State railways; locomotive boilers are used. The establishment has been at work for the last two years, but no results are published, as they are considered the property of the Government. Private firms can, however, have their coals tested and reported upon.

(11) The Imperial Marine Station, Dantzig.

(12) Boiler Insurance Company at Magdeburg.

The above is a slight outline of the work already done in this direction.

With the view of obtaining the opinions of those interested in starting a fuel-testing station, I ask you kindly to give this letter publicity. If the necessary sum can be raised, we may hope to have before long a practical and useful establishment in London, and to gain from it many interesting practical results respecting the combustion of fuels. BRYAN DONKIN, JUN.

Bermondsey, S.E., June 11.

## The Geometric Interpretation of Monge's Differential Equation to all Conics—the Sought Found.

THE question of the true geometric interpretation of the Mongian equation has been often considered by mathematicians. In the first place, we have the late Dr. Boole's statement that "here our powers of geometrical interpretation fail, and results such as this can scarcely be otherwise useful than as a registry of integrable forms" ("Diff. Equ.," pp. 19–20). We have next two attempts to interpret the equation geometrically. The first of these propositions, by Lieut.-Colonel Cunningham, is that "the eccentricity of the osculating conic of a given conic is constant all round the latter" (*Quarterly Journal*, vol. xiv. 229); the second, by Prof. Sylvester, is that "the differential equation of a conic is satisfied at the sextactic points of any curve" (*Amer. Journ. Math.*, vol. ix. p. 19). I have elsewhere considered both these interpretations in detail, and I have pointed out that both of them are irrelevant; the first of them is, in fact, the geometric interpretation, not of the Mongian equation, but of one of its five first integrals which I have actually calculated (Proc. Asiatic Soc. Bengal, 1888, pp. 74–86); the second is out of mark as failing to furnish such a property of the conic as would lead to a geometrical quantity which vanishes at every point of every conic (Journal Asiatic Soc. Bengal, 1887, Part 2, p. 143). In this note I will briefly mention the true geometric interpretation which I have recently discovered.

Consider the osculating conic at any point, P, of a given curve; the centre, O, of the conic is the centre of aberrancy at P, and as P travels along the given curve, the locus of O will be another curve, which we may conveniently call the *aberrancy curve*. Take rectangular axes through any origin; let $(x, y)$ be the given point P, and $\alpha$, $\beta$ the co-ordinates of the centre of aberrancy. Then it can be shown without much difficulty that

$$\alpha = x - \frac{3qr}{3qs - 5r^2},$$

$$\beta = y - \frac{3q(pr - 3q^2)}{3qs - 5r^2},$$

whence

$$\frac{d\alpha}{dx} = \lambda T, \quad \frac{d\beta}{dx} = \mu T,$$

where

$$\lambda = \frac{r}{(3qs - 5r^2)^2}, \quad \mu = \frac{pr - 3q^2}{(3qs - 5r^2)^2},$$

$$T \equiv 9q^2t - 45qrs + 40r^3,$$

$p, q, r, s, t$ being, as usual, the successive differential coefficients of $y$ with respect to $x$.

If $d\psi$ be the angle between two consecutive axes of aberrancy, $ds$ the element of arc, and $\rho$ the radius of curvature of the aberrancy curve, we have

$$\rho = \frac{ds}{d\psi}, \quad ds^2 = d\alpha^2 + d\beta^2,$$

whence

$$\rho = (\lambda^2 + \mu^2)^{\frac{1}{2}} \,.\, T \,.\, \frac{dx}{d\psi}.$$

But it is easy to show that

$$\frac{d\psi}{dx} = \frac{q(3qs - 5r^2)}{r^2 + (rp - 3q^2)^2},$$

so that

$$\rho = T \,.\, \frac{\{r^2 + (rp - 3q^2)^2\}^{\frac{3}{2}}}{q(3qs - 5r^2)^3}.$$

Now, $T = 0$ is Monge's differential equation to all conics, and when $T = 0$ we have $\rho = 0$. Hence, clearly, the true geometric interpretation of the Mongian equation is:

*The radius of curvature of the aberrancy curve vanishes at every point of every conic.*[1]

This geometrical interpretation will be found to satisfy all the tests which every true geometrical interpretation ought to satisfy, and I believe that this is the interpretation which, during the last thirty years, has been sought for by mathematicians, ever since Dr. Boole wrote his now famous lines. I will not take up the valuable space of these columns with the details of calculation: they will be found fully set forth in two of my papers which will be read next month before the Asiatic Society of Bengal, and will in due course be published in the Journal.

Calcutta, May 18. ASUTOSH MUKHOPADHYAY.

# PERSONAL IDENTIFICATION AND DESCRIPTION.[2]

I.

IT is strange that we should not have acquired more power of describing form and personal features than we actually possess. For my own part I have

[1] The differential equation of all parabolas,

$$3qs - 5r^2 = 0,$$

is also easily interpreted, viz. calling the distance OP between the given point and the centre of aberrancy the *radius of aberrancy*, and the reciprocal of this (= I) the *index of aberrancy*, we have, easily,

$$I = \frac{3qs - 5r^2}{3q\{r^2 + (rp - 3q^2)^2\}^{\frac{1}{2}}},$$

so that the interpretation is that *the index of aberrancy vanishes at every point of every parabola.*

[2] The substance of a Lecture given by Francis Galton, F.R.S., at the Royal Institution on Friday evening, May 25, 1888.

frequently chafed under the sense of inability to verbally explain hereditary resemblances and types of features, and to describe irregular outlines of many different kinds, which I will not now particularize. At last I tried to relieve myself as far as might be from this embarrasment, and took considerable trouble, and made many experiments. The net result is that while there appear to be many ways of approximately effecting what is wanted, it is difficult as yet to select the best of them with enough assurance to justify a plunge into a rather serious undertaking. According to the French proverb, the better has thus far proved an enemy to the passably good, so I cannot go much into detail at present, but will chiefly dwell on general principles.

*Measure of Resemblance.*—We recognize different degrees of likeness and unlikeness, though I am not aware that attempts have been as yet made to measure them. This can be done if we take for our unit the *least discernible difference.* The application of this principle to irregular contours is particularly easy. Fig. 1 shows two such contours, A and B, which might be meteorological, geographical, or anything else. They are drawn with firm lines, but of different strengths for the sake of distinction. They contain the same area, and are so superimposed as to lie as fairly one over the other as may be. Now draw a broken contour which we will call C, equally subdividing the intervals between A and B; then C will be more like A than B was. Again draw a dotted contour, D, equally subdividing the intervals between C and A; the likeness of D to A will be again closer. Continue to act on the same

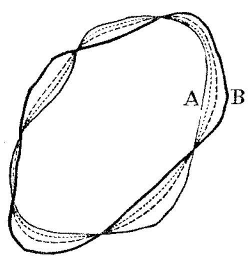


FIG. 1.

principle until a stage is reached when the contour last drawn is undistinguishable from A. Suppose it to be the fourth stage; then as $2^4 = 16$, there are 16 grades of least-discernible differences between A and B. If one of the contours differs greatly in a single or few respects from the other, reservation may be made of those peculiarities. Thus, if A has a deep notch in its lower right-hand border, we might either state that fact, and say that in other respects it differed from B by only 16 grades of unlikeness, or we might make no reservation, and continue subdividing until all trace of the notch was smoothed away. It is purely a matter of convenience which course should be adopted in any given case. The measurement of resemblance by units of least-discernible differences is applicable to shades, colours, sounds, tastes, and to sense-indications generally. There is no such thing as infinite unlikeness. A point as perceived by the sense of sight is not a mathematical point, but an object so small that its shape ceases to be discernible. Mathematically, it requires an infinitude of points to make a short line; sensibly, it requires a finite and not a large number of what the vision reckons as points, to do so. If from thirty to forty points were dotted in a row across the disk of the moon, they would appear to the naked eyes of most persons as a continous line.

*Description within Specified Limits.*—It is impossible to verbally define an irregular contour with such precision that a drawing made from the description shall be undistinguishable from the original, but we may be content with a lower achievement. Much would be gained if we could refer to a standard collection of contours drawn with double lines, and say that the contour in question falls between the double lines of the contour catalogued as number so-and-so. This would at least tell us that none of the very many contours that fell outside the specified limits could be the one to which the description applied. It is an approximate and a negative method of identification. Suppose the contour to be a profile, and for simplicity's sake let us suppose it to be only the portion of a profile that lies below the notch that separates the brow from the nose and above the parting between the lips, and such as is afforded by a shadow sharply cast upon the wall by a single source of light, such as is excellently seen when a person stands side-ways between the electric lantern and the screen in a lecture-room. All human profiles of this kind, when they have been reduced to a uniform vertical

FIG. 2.

scale, fall within a small space. I have taken those given by Lavater, which are in many cases of extreme shapes, and have added others of English faces, and find that they all fall within the space shown in Fig. 2. The outer and inner limits of the space are of course not the profiles of any real faces, but the limits of many profiles, some of which are exceptional at one point and others at another. We can classify the great majority of profiles so that the whole of each class shall be included between the double borders of one, two, or some small number of standard portraits such as Fig. 3. I am as yet unprepared to say how near together the double borders of such standard portraits should be; in other words, what is the smallest number of grades of unlikeness that we can satisfactorily deal with. The process of sorting profiles into their proper classes and of gradually

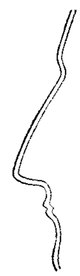

FIG. 3.

building up a well-selected standard collection, is a laborious undertaking if attempted by any obvious way, but I believe it can be effected with comparative ease on the basis of measurements, as will be explained later on, and by an apparatus that will be described.

*Classification of Sets of Measures.*—Prisoners are now identified in France by the measures of their heads and limbs, the set of measures of each suspected person being compared with the sets that severally refer to each of many thousands of convicts. This idea, and the practical application of it, is due to M. Alphonse Bertillon. The actual method by which this is done is not all that could be theoretically desired, but it is said to be effective in action, and enables the authorities quickly to assure themselves whether the suspected person is or is not an old malefactor. The primary measures in the classification are four—

namely, the head length, head breadth, foot length, and middle-finger length of the left foot and hand respectively. Each of these is classified according as it is large, medium, or small. There are thus three, and only three, divisions of head lengths, each of which is subdivided into three divisions of head breadth; again, each of these is further subdivided into three of foot length, and these again into three of middle-finger length; thus the number of primary classes is equal to three multiplied into itself four times—that is to say, their number is eighty-one, and a separate pigeon-hole is assigned to each. All the exact measures and other notes on each criminal are written on the same card, and this card is stored in its appropriate pigeon-hole. The contents of each pigeon-hole are themselves sub-sorted on the same principle of three-fold classification in respect to other measures. This process can, of course, be extended indefinitely, but how far it admits of being carried on advantageously is another question. The fault of all hard-and-fast lines of classification, when variability is continuous, is the doubt where to find values that are near the limits between two adjacent classes. Let us take the case of stature, for

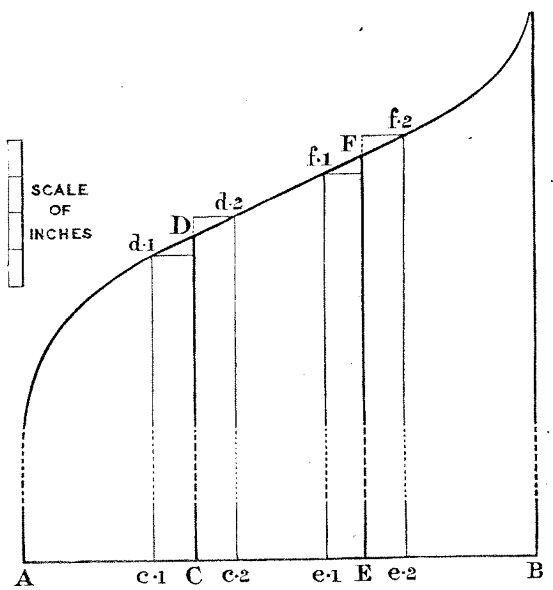


Fig. 4.

illustration of what must occur in every case, representing its distribution by what I have called a "scheme," as shown in Fig. 4.

Here the statures of any large group of persons are represented by lines of proportionate length. The lines are arranged side by side at equal distances apart on a base, A B, of convenient length. A curve drawn through their tops gives the upper boundary of the scheme; the lines themselves are then wiped out, having served their purpose. If the base A B be divided into three equal parts, and perpendiculars, C D, E F, be erected at the divisions between them, reaching from the base up to the curve, then the lengths of those perpendiculars are proportionate to the limiting values between the small and the medium group, and the medium and the large group, respectively. The difference between these perpendiculars in the case of stature is about 2·3 inches. In other words, the shortest and tallest men in the medium class differ only by that amount. We have next to consider how much ought reasonably to be allowed for error of measurement. Considering that a man differs in height by a full third of an inch between the time of getting up in the morning and lying down at night; considering also that measures are recorded to the nearest tenth of an inch at the closest, also the many uncertainties connected with the measurement of stature, it would be rash not to allow for a possible error of at least ± half an inch. Prolong C D, and note the points upon it at the distance of half an inch above and below D; draw horizontal lines from those points to meet the curve at *d*.1, *d*.2, and from the points of intersection drop perpendiculars reaching the base at *c*.1, *c*.2. A similar figure is drawn at F. Then the ratio borne by the uncertain entries to the whole number of entries is as $c_1c_2 + e_1e_2$ to AB. This, as seen by the diagram, is a very serious proportion. There is a dilemma which those who adopt hard-and-fast lines of classification cannot avoid: either the fringe of uncertainty is dangerously wide, or else the delicacy with which measures are made is not turned to anything like its full account. If the delicacy is small, the fringe of uncertainty must be very wide; if the delicacy is great, the fringe will be narrow; but then the other advantages of possessing delicate observations are wasted through employing only a few classes. The bodily measurements are so dependent on one another that we cannot afford to neglect small distinctions. Thus long feet and long middle-fingers usually go together. We therefore want to know whether the long feet in some particular person are accompanied by particularly long, or moderately long, or relatively short fingers, though the fingers may in the two last cases be long as compared with those of the general population, and will be treated as long in M. Bertillon's system of classes. Certainly his eighty-one combinations are far from being equally probable. The more numerous the measures the greater would be their interdependence, and the more unequal would be the distribution of cases among the various possible combinations of large, small, and medium values. No attempt has yet been made to estimate the degree of their interdependence. I am therefore having the above measurements (with slight necessary variation) recorded at my anthropometric laboratory for the purpose of doing so. This laboratory, I may add, is now open to public use under reasonable restrictions. It is entered from the Science Collections in the Western Galleries at South Kensington.

*Mechanical Selector.*—Feeling the advantage of possessing a method of classification that did not proceed upon hard-and-fast lines, I contrived an apparatus that is quite independent of them, and which I call a mechanical selector. Its object is to find which set out of a standard collection of many sets of measures, resembles any one given set within specified degrees of unlikeness. No one measure in any of the sets selected by the instrument can differ from the corresponding measure in the given set, by more than a specified value. The apparatus is very simple, it applies to sets of measures of every description, and ought to act on a large scale with great rapidity, and as well as it does on a small one, testing several hundred sets by each movement. It relieves the eye and brain from the intolerable strain of tediously comparing a set of many measures with each successive set of a large series, in doing which a mental allowance has to be made for a *plus* or *minus* deviation of a specified amount in every entry. It is not my business to look after prisoners, and I do not fully know what need may really exist for new methods of quickly identifying suspected persons. If there be any real need, I should think that this apparatus, which is contrived for other purposes, might, after obvious modifications, supply it.

The apparatus consists of a large number of strips of card or metal, *c*1, *c*2 (Fig. 5), say 8 or 9 inches long, and having a common axis, A, passing through all their smaller ends. A tilting-frame, T, which turns on the same axis, has a front cross-bar, F, on which the tips of the larger ends of all the cards rest whenever the machine is left alone. In this condition a counterpoise at the other end of T suffices to overcome the weight of all the cards, and this heavy end of T lies on the base-board S. When the heavy end of T is lifted, as in Fig. 5, its front-bar is of course depressed, and the cards being individually acted on by their own weights are free to descend with the cross-bar unless they are otherwise prevented. The lower edge of each card is variously notched to indicate the measures of the person it represents. Only four notches are shown in the figure, but six could easily be employed in a card of eight or nine inches long, allowing compartments of 1 inch in length, to each of six different measures. The position of the notch in the compartment allotted to it, indicates the corresponding measure according to a suitable scale. When the notch is in the middle of a compartment, it means that the measure is of mediocre amount; when at one end of it, the measure is of some specified large value or of any other value above that; when at the other end, the measure is of some specified small value or of any other value below it. Intermediate positions represent intermediate values according to the scale. Each of the cards corresponds to one of the sets of measures in the standard collection. The set of measures of the given person are indicated by the positions of parallel strings or wires, one for each measure, that are stretched

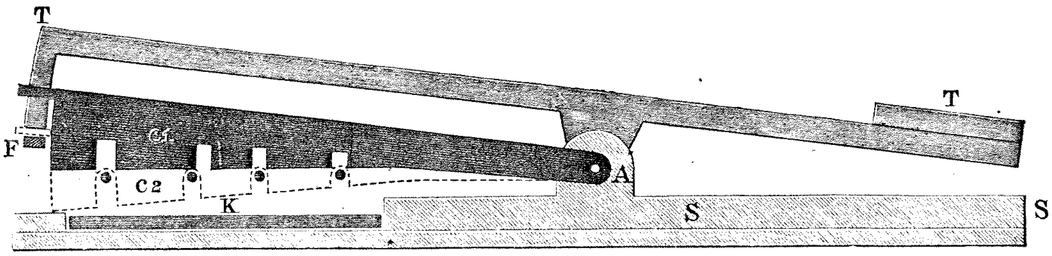


FIG. 5.—Section of the apparatus, but the bridge and rod are not shown, only the section of the wires.

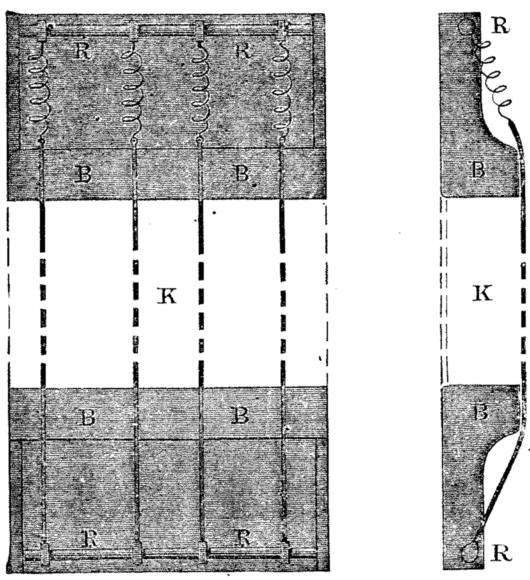


FIG. 6*a*. FIG. 6*b*.
Plan and section of the key-board K.

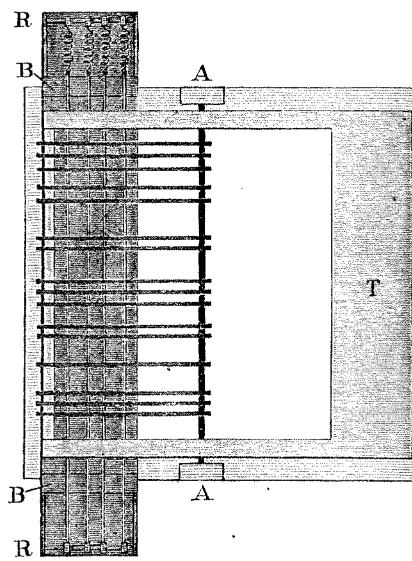


FIG. 7.—Reduced plan of complete apparatus.

*Explanation*:—A, the common axis; *c*1, *c*2, the cards T; T, tilting-frame, turning on A (the cards rest by their front ends on F, the front cross-bar of T, at the time when the heavy hinder end of T rests on the base-board S; K, key-board, in which R, R are the rods between which the wires stretch; B, B, are the bridges over which the wires pass.

across bridges at either end of a long board set crossways to the cards. Their positions on the bridges are adjusted by the same scale as that by which the notches were cut in the cards. Figs. 6*a* and 6*b* are views of this portion of the apparatus, which acts as a key, and is of about 30 inches in effective length. The whole is shown in working position in Fig. 7. When the key is slid into its place, and the heavy end of the tilting-frame T is raised, all the cards are free to descend so far as the tilting-frame is concerned, but they are checked by one or more of the wires from descending below a particular level, except those few, if any, whose notches correspond throughout to the positions of the underlying wires. This is the case with the card *c*2, drawn with a dotted outline, but not with *c*1, which rests upon the third wire, counting from the axis. As the wires have to sustain the weight of all or nearly all the cards, frequent narrow bridges must be interposed between the main bridges to sustain the wires from point to point. The cards should be divided into batches by partitions corresponding to these interposed bridges, else they may press sideways with enough friction to interfere with their free independent action. Neither these interposed bridges nor the partitions are drawn in the figure. The method of adjusting the wires there shown is simply by sliding the rings to which they are attached at either end, along the rod which passes through them. It is easy to arrange a more delicate method of effecting this if desired. Hitherto I have snipped out the notches in the cards with a cutter made on the same principle as that used by railway guards in marking the tickets of travellers. The width of the notch is greater than the width of the wire by an amount proportionate to the allowance intended to be made for error of measurement, and also for that due to mechanical misfit. There is room for 500 cards or metal strips to be arranged in sufficiently loose order within the width of 30 inches, and a key of that effective length would test all these by a single movement. It could also be applied in quick succession to any number of other collections of 500 in each.

*Measurement of Profiles.*—The sharp outline of a photograph in profile admits of more easy and precise measurement than the yielding outline of the face itself. The measurable differences between the profiles of different persons are small, but they are much more numerous than might have been expected, and they are more independent of one another than those of the limbs. I suspect that measures of the profile may be nearly as trustworthy as those of the limbs for approximate identification—that is, for excluding a very large proportion of persons from the possibility of being mistaken for the one whose measurements are given. The measurement of a profile enables us to use a mechanical selector for finding those in a large standard collection to which they nearly correspond. From the selection thus made the eye could easily make a further selection of those that suited best in other respects. A mechanical selector also enables us to quickly build up a standard collection step by step, by telling us whether or no each fresh set of measures falls within the limits of any of those already collected. If it does, we know that it is already provided for; if not, a new card must be added to the collection. There will be no fear of duplications, as every freshly-added standard will differ from all its predecessors by more than the specified range of permitted differences. After numerous trials of different methods for comparing portraits successively by the eye, I have found none so handy and generally efficient as a double-image prism, which I largely used in my earlier attempts in making composite portraits. As regards the most convenient measurements to be applied to a profile for use with the selector, I am unable as yet to speak decidedly. If we are dealing merely with a black silhouette, such as the shadow cast on a wall by a small or brilliant light, the best line from which to measure seems to be B C in Fig. 8; namely, that which touches both the concavity of the notch between the brow and nose, and the convexity of the chin. I have taken a considerable number of measures from the line that touches the brow and chin, but am now inclined to prefer the former line. A sharp unit of measurement is given by the distance between the above line and another drawn parallel to it just touching the nose, as at N in the figure. A small uncertainty in the direction of B C has but a very trifling effect on this distance. By dividing the interval between these parallel lines into four parts, and drawing a line through the third of the divisions, parallel to B C, we obtain the two important points of reference, M and R. M is a particularly well-defined point, from which O is determined by dropping a perpendicular from M upon B C. O seems the best of all points from which to measure. It is excellently placed for defining the shape and position of the notch between the nose and the upper lip, which is perhaps the most distinctive feature in the profile. O L can be determined with some precision; O B and O C are but coarse measurements. In addition to these and other obvious measures, such as one or more to define the projection of the lips, it would be well to measure the radius of the circle of curvature of the depression at B, also of that between the nose and the lip, for they are both very variable and very distinctive. So is the general slope of the base of the nose. The difficulty lies not in selecting a few measures that will go far towards negatively identifying a face, but in selecting the best—namely, those that can be most precisely determined, are most independent of each other, most variable, and most expressive of the general form of the profile. I have tried many different sets, and found all to be more or less efficient, but have not yet decided to my own satisfaction which to adopt.

A closer definition of a profile or other curve, can be based upon the standard to which it is referred. Short cross-lines may be drawn at critical positions between the two outlines of the standard, and be each divided into eight equal parts. The intersection of the cross-lines with the outer border would always count as 0, that with the inner border as 8, and the intermediate divisions would count from 1 to 7. As the cross-lines are very short, a single numeral would thus define the position of a point in any one of them, with perhaps as much precision as the naked eye could utilize. By employing as

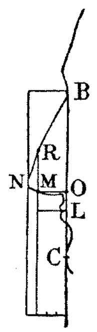


Fig. 8.

many figures as there are cross-lines in the standard, each successive figure for each successive cross-line, a corresponding number of points in the profile would be accurately fixed. Suppose a total of nine figures to be given, together with a standard collection of under a thousand doubly outlined portraits, each with six cross-lines. The first three figures would specify the catalogue number of the portrait to be referred to, and the remaining six figures would determine with much accuracy, six points in the outline of the portrait that it is desired to describe.

I have not succeeded in contriving an instrument that shall directly compare a given profile with those in a standard collection, and which shall at the same time act with anything like the simplicity of the above, and with the same quick decision in acceptance or rejection. Still, I recognize some waste of opportunity in not utilizing the power of varying the depths of the notches in the cards, independently of their longitudinal position.

I shall have next to speak of other data that may serve for personal identification, and especially on the marks left by blackened finger-tips upon paper.

(*To be continued.*)

## *SOAP-BUBBLES.*

SOAP-BUBBLES fill the same happy position as do those charming books in which Lewis Carroll describes the adventures of Alice, in that they serve equally to delight the young and to attract the old. Clerk-Maxwell has mentioned the fact that on an Etruscan vase in the Louvre are seen the figures of children amusing themselves with bubbles, while to-day the same subject is being forced on the attention of the world done already by Messrs. Cunningham and Weldon under the most unfavourable conditions that it cannot but be anticipated that when a number of investigators are working under favourable conditions on different groups, but with a common object in view, results of the greatest scientific and practical importance will accrue.

The ceremony on Saturday will be interesting and important. Many of the leading biologists in England will be present, but unfortunately the eminent President of the Association, Prof. Huxley, will be absent on account of ill-health, and so, unfortunately, will Prof. Moseley, one of its most ardent and generous supporters. The Fishmongers' Company have added to their munificent patronage of the institution by undertaking the entertainment of the numerous guests who have been invited to the ceremony; and the Association will be launched on its career of usefulness in a manner worthy of its aspirations, and satisfactory in the highest degree to its energetic promoters.

G. C. B.

## PERSONAL IDENTIFICATION AND DESCRIPTION.[1]

II.

PERSONAL characteristics exist in much more minute particulars than those described in the last article. Leaving aside microscopic peculiarities which are of unknown multitudes, such as might be studied in the 800,000,000 specimens cut by a microtome, say of one two-thousandth part of an inch in thickness, and one tenth of an inch each way in area, out of the 4000 cubic inches or so of the flesh, fat, and bone of a single average human body, there are many that are visible with or without the aid of a lens.

The markings in the iris of the eye are of the above kind; they have been never adequately studied except by the makers of artificial eyes, who recognize thousands of varieties of them. These markings well deserve being photographed from life on an enlarged scae. I shall not dwell now upon these, nor on such peculiarities as those of hand-writing, nor on the bifurcations and interlacements of the superficial veins, nor on the shape and convolutions of the ear. These all admit of brief approximate description by the method explained in the last article—namely, by reference to the number in a standard collection of the specimen that shall not differ from it by more than a specified number of units of unlikeness. I fully explained what a unit of unlikeness was, and certain mechanical means by which a given set of measures could be compared with great ease and by a single movement with every set simultaneously, in a large standard collection of sets of measures.

Perhaps the most beautiful and characteristic of all superficial marks are the small furrows with the intervening ridges and their pores that are disposed in a singularly complex yet even order on the under surfaces of the hands and the feet. I do not now speak of the large wrinkles in which chiromantists delight, and which may be compared to the creases in an old coat or to the deep folds in the hide of a rhinoceros, but of the fine lines of which the buttered fingers of children are apt to stamp impressions on the margins of the books they handle, that leave little to be desired on the score of distinctness. These lines are found to take their origin from various centres, one of which lies in the under surface of each finger-tip. They proceed from their several centres in spirals and whorls, and distribute themselves in beautiful patterns over the whole palmar surface. A corresponding system covers the soles of the feet. The same lines appear with little modification in the hands and feet of monkeys. They appear to have been carefully studied for the first time by Purkinje in 1822; since then they have attracted the notice of many writers and physiologists, the fullest and latest of whom is Kollman, who has published a pamphlet upon them, "Tastapparat der Hand" (Leipzig, 1883), in which their physiological significance is fully discussed. Into that part of the subject I am not going to enter here. It has occurred independently to many persons to propose finger-marks as a means of identification. In the last century, Bewick in one of the vignettes in the "History of Birds" gave a woodcut of his own thumb-mark, which is the first clear impression that I know of. Some of the latest specimens that I have seen are by Mr. Gilbert Thomson, an officer of the American Geological Survey, who, being in Arizona, and having to make his orders for payment on a camp suttler, hit upon the expedient of using his own thumb-mark to serve the same purpose as the elaborate scroll engraved on blank cheques — namely, to make the alteration of figures written on it, impossible without detection. I possess copies of two of his cheques. A San Francisco photographer, Mr. Tabor, made enlarged photographs of the finger-marks of Chinese, and his proposal seems to have been seriously considered as a means of identifying Chinese immigrants. I may say that I can obtain no verification of a common statement that the method is in actual use in the prisons of China. The thumb-mark has been used there as elsewhere in attestation of deeds, much as a man might make an impression with a common seal, not his own, and say, "This is my act and deed"; but I cannot hear of any elaborate system of finger-marks having ever been employed in China for the identification of prisoners. It was, however, largely used in India, by Sir William Herschel, twenty-eight years ago, when he was an officer of the Bengal Civil Service. He found it to be most successful in preventing personation, and in putting an end to disputes about the authenticity of deeds. He described his method fully in NATURE, in 1880 (vol. xxiii. p. 76), which should be referred to by the reader; also a paper by Mr. Faulds in the next volume. I may also refer to articles in the American journal *Science*, 1886 (vol. viii. pp. 166 and 212).

The question arises whether these finger-marks remain unaltered throughout the life of the same person. In reply to this, I am enabled to submit a most interesting piece of evidence, which thus far is unique, through the kindness of Sir Wm. Herschel. It consists of the imprints of the two first fingers of his own hand, made in 1860 and in 1888 respectively; that is, at periods separated by an interval of twenty-eight years. I have also two intermediate imprints, made by him in 1874 and in 1883 respectively. The imprints of 1860 and 1888 have now been photographed on an enlarged scale, direct upon the engraver's block, whence Figs. 9 and 11 are cut; these woodcuts may therefore be relied on as very correct representations. Fig. 10 contains the portion of Fig. 9 to which I am about to draw attention. On first examining these and other finger-marks, the eye wanders and becomes confused, not knowing where to fix itself; the points shown in Fig. 10 are those it should select. They are those at which each new furrow makes its first appearance. The furrows may originate in two principal ways, which are not always clearly distinguishable: (1) the new furrow may arise in the middle of a ridge; (2) a single furrow may bifurcate and form a letter Y. The distinction between (1) and (2) is not greatly to be trusted, because one of the sides of the ridge in case (1) may become worn, or be narrow and low, and not always leave an imprint, thus converting it into case (2); conversely case (2) may be changed into (1). The position of the origin of the new furrow is, however, none the less defined. I have noted the furrow-heads and bifurcations of furrows in Fig. 9, and shown them separately in Fig. 10. The reader will be able

[1] The substance of a Lecture given by Francis Galton, F.R.S., at the Royal Institution on Friday evening, May 25, 1888. Continued from p. 177.

to identify these positions with the aid of a pair of compasses, and he will find that they persist unchanged in Fig. 11, though there is occasional uncertainty between cases (1) and (2). Also there is a little confusion in the middle of the small triangular space that separates two distinct systems of furrows, much as eddies separate the stream

FIG. 9.—Enlarged impressions of the fore and middle finger tips of the right hand of Sir William Herschel, made in the year 1860.

FIG. 10.—Positions of furrow-heads and bifurcations of furrows, in Fig. 9.

FIG. 11.—Enlarged impressions of the fore and middle finger tips of the right hand of Sir William Herschel, made in the year 1888.

lines of adjacent currents converging from opposite directions. A careful comparison of Figs. 9 and 11 is a most instructive study of the effects of age. There is an obvious amount of wearing and of coarseness in the latter, but the main features in both are the same. I happen to possess a very convenient little apparatus for recording the positions of furrow-heads. It is a slight and small, but well-made wooden pentagraph, multiplying five-fold, in which a very low-power microscope, *with coarse cross-wires*, forms the axis of the short limb, and a pencil-holder forms the axis of the long limb. I contrived it for quite another use—namely, the measurement of the length of wings of moths in some rather extensive experiments that are now being made for me in pedigree moth-breeding. It has proved very serviceable in this inquiry also, and was much used in measuring the profiles spoken of in the last article. Without some moderate magnifying power, the finger-marks cannot be properly studied. It is a convenient plan, in default of better methods, to prick holes with a needle through the furrow-heads into a separate piece of paper, where they can be studied without risk of confusing the eye. There are peculiarities often found in furrows that do not appear in these particular specimens, to which I will not further refer. In Fig. 10 the form of the origin of the spirals is just indicated. These forms are various; they may be in single or in multiple lines, and the earlier turns may form long loops or be nearly circular. My own ten fingers show at least four distinct varieties.

Notwithstanding the experience of others to the contrary, I find it not easy to make clear and perfect impressions of the fingers. The proper plan seems to be to cover a flat surface, like that of a piece of glass or zinc, with a thin and even coat of paint, whether it be printers' ink or Indian ink rubbed into a thick paste, and to press the finger lightly upon it so that the ridges only shall become inked, then the inked fingers are pressed on smooth and slightly damped paper. If a plate of glass be smoked over a paraffin lamp, a beautiful negative impression may be made on it by the finger, which will show well as a lantern transparency. The blackened finger may afterwards be made to leave a positive impression on a piece of paper, that requires to be varnished if it is to be rendered permanent. All this is rather dirty work, but people do not seem to object to it; rivalry and the hope of making continually better impressions carries them on. It is troublesome to make plaster casts; modelling-clay has been proposed; hard wax, such as dentists use, acts fairly well; sealing-wax is excellent if the heat can be tolerated; I have some good impressions in it. For the mere study of the marks, no plan is better than that of rubbing a little thick paste of chalk ("prepared chalk") and water or sized water upon the finger. The chalk lies in the furrows and defines them. They could then be excellently photographed on an enlarged scale. My own photographic apparatus is not at hand, or I should have experimented in this. When notes of the furrow-heads and of the initial shape of the spiral have been made, the measurements would admit of comparison with those in catalogued sets, by means of a numerical arrangement, or even by the mechanical selector described in the last article. If a cleanly and simple way could be discovered of taking durable impressions of the finger tips, there would be little doubt of its being serviceable in more than one way.

In concluding my remarks, I should say that one of the inducements to making these inquiries into personal identification has been to discover independent features suitable for hereditary investigation. It has long been my hope, though utterly without direct experimental corroboration thus far, that if a considerable number of variable and independent features could be catalogued, it might be possible to trace kinship with considerable certainty. It does not at all follow because a man inherits his main features from some one ancestor, that he may not also inherit a large number of minor and commonly overlooked features from many ancestors. Therefore it is not improbable, and worth taking pains to inquire whether each person may not carry visibly about his body undeniable evidence of his parentage and near kinships.