

## CHAPTER XII

### PHOTOGRAPHIC RESEARCHES AND PORTRAITURE

“Whatever he touched he was sure to draw from it something that it had never before yielded, and he was wholly free from that familiarity which comes to the professed student in every branch of science, and blinds the mental eye to the significance of things which are overlooked because always in view.” *Nature* on CHARLES DARWIN, Vol. XXVI, p. 147.

WE have seen in the preceding chapter how Galton supposed composite portraiture to be connected fundamentally with psychological inquiry. Galton developed composite photography in his search for a method of ascertaining whether physiognomy is an index to mind, i.e. whether facial characteristics are correlated with mental traits. The actual method he employed, however, was curiously enough suggested to him as a result of his attempts to illustrate the multiple geographical features of a country, where he wanted more than could be readily exhibited on the usual type of maps. Galton's own idea of composite portraiture would fully justify our discussing it under the heading of “Psychometric Investigations.” But as Galton's contributions to scientific photography are numerous and important, it has seemed to me desirable to devote an entire chapter to the subject, although much that will be contained in this chapter has great psychometric interest.

Galton's contributions to photographic science break up into six sections, namely:

- (A) Composite Photography.
- (B) Bi-projections by Photography.
- (C) Analytical Photography.
- (D) Measurements by Photography.
- (E) Indexing and Numeralisation of Portraits.
- (F) Measurements of Resemblance, chiefly by photographs.

We shall also include in this chapter, as closely related to our present topics, the subjects of the indexing of portraits and the telegraphy of portraits. The matters to be discussed occupied Galton's mind almost continuously from 1878 to 1911, i.e. more than thirty years. They had singular fascination for him not only because they combined fairly simple mathematical investigation with mechanical invention and experiment, but also because they were closely associated with psychological and hereditary inquiries.

#### (A) *Composite Photography.*

There is a paper on combining various data in maps which explains the origin of Galton's inquiries into composite photography. As he himself says in a paper of 1878:

“It was while endeavouring to elicit the principal criminal types by methods of optical

superimposition of the portraits, such as I had frequently employed with maps and meteorological traces, that the idea of composite figures first occurred to me<sup>1</sup>."

This paper by Galton, which I had some difficulty in locating, and of which no copy could be found in his collections, is entitled: "On means of combining various Data in Maps and Diagrams<sup>2</sup>." Galton therein refers again to his stereoscopic map method<sup>3</sup>, which plan he regrets had not yet been adopted. He says that it needs good models, but that the number of these increases every year, as the then recent French Geographical Exposition demonstrated. He exhibited in the Loan Exhibition stereoscopic views of models taken by the Royal Engineers, but I do not know what subjects they represented. He suggested the stereoscope, not only as a means of showing things in the solid, but of superposing plans and maps for comparative purposes.

He next turns to superposition by means of a telescope; he remarks that if one half of the object-glass be covered up, the sole effect on the image of a distant object will be to reduce its brilliancy by a half. Now let us suppose two lenses placed one in front of one half of the object-glass and the other in front of the other half, each with its own object at its focal distance; the two objects will then be combined superposed in the field of view of the telescope. Instead of two lenses four might be distributed over the area of the object-glass to combine four objects, etc. Actually Galton placed his telescope vertically and ran a horizontal tramway under the objective; in the blackened roof of a 'tramcar' a number of lenses were inserted and opposite each on the floor of the carriage its own object at the focal distance of the lens. If now lens 1 be brought under the objective we see only object 1, as we push the carriage farther lens 1 tends to pass out of the field and lens 2 to share the field; thus different intensities of objects 1 and 2 can be combined. A further push of the carriage causes 2 alone to be seen, and the process continued combines it with 3, and so on. Galton's model had six lenses of the same focal distance and size in the roof of his carriage. By this means a series of geographical data which would overcrowd any single map can be combined in sets of two.

"It affords a peculiarly suitable method for picturing changes whether in physical or political geography. I will not describe the mechanism by which complex and powerful instruments of this kind might be constructed; where the images should be thrown by a lime light on a screen, and a string of perhaps only three large achromatic collimators would serve for an indefinite number of pictures." (p. 315.)

That Galton should have spoken of the old 'wheel of life' in connection with his apparatus, shows that he had a foreshadowing of the modern cinematograph. By using lenses of different focal length objects at different distances could be combined, and by using inclined mirrors facing definite parts of the object-glass the objects need not be placed in parallel planes.

<sup>1</sup> *Journal of the Anthropological Institute*, Vol. VIII, p. 135, 1878. In this paper (ftn. p. 135) Galton gives 1878, instead of 1876, for the year of the Map paper.

<sup>2</sup> South Kensington Museum Conferences held in connection with the Special Loan Collection of Scientific Apparatus, 1876; Chemistry, Biology, Physical Geography, Geology, Mineralogy and Meteorology (pp. 312-15). London, Chapman and Hall.

<sup>3</sup> See our p. 33.

Galton very soon discovered that the methods of optically combining images are very various indeed. Thus in a paper of 1878 he writes<sup>1</sup>:

"I have tried many other plans; indeed the possible methods of optically superimposing two or more images are very numerous. Thus I have used a sextant (with its telescope attached); also strips of mirrors placed at different angles, their several reflections being simultaneously viewed through a telescope. I have also used a divided lens, like two stereoscopic lenses brought close together, in front of the object-glass of a telescope.

I have not yet had an opportunity of superimposing images by placing glass negatives in separate magic lanterns, all converging upon the same screen; but this or even a simple dioramic apparatus would be very suitable for exhibiting composite effects to an audience, and if the electric light were used for illumination, the effect on the screen could be photographed at once. It would also be possible to construct a camera with a long focus, and many slightly divergent object-glasses, each throwing an image of a separate glass negative upon the same sensitised plate." (p. 140.)

Among Galton's instruments in the Galton Laboratory is a piece of apparatus for compounding six objects. It is of the following nature. Six different photographs, arranged symmetrically round a blackened screen, face six different object-glasses which, set round the base of a conical tube, form a composite image of all six on a small focusing screen towards the vertex of the cone. This image is examined by an eye-piece passing through the centre of the vertical screen and entering centrally the base of the cone. The focusing screen is only about 2 inches in diameter, but the image is magnified by the eye-piece. Six components can be superposed and examined visually, but there does not seem any special provision in the

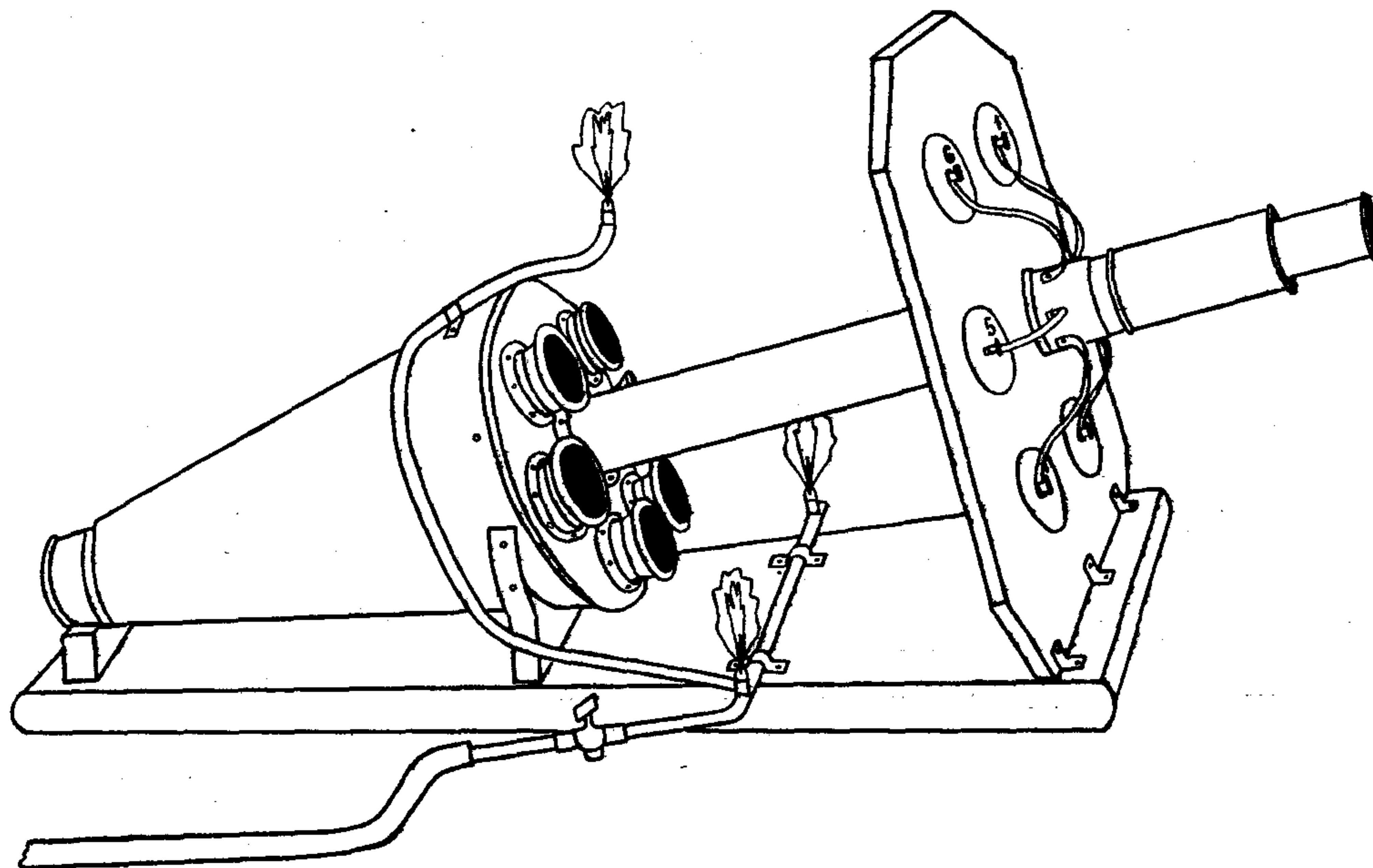


Diagram i.

<sup>1</sup> "Composite Portraits," made by combining those of many different persons into a single resultant figure. *Journal of the Anthropological Institute*, Vol. VIII, pp. 132-42, 1878.

apparatus for photographing the composite image either from below the screen or from the eye-piece side.

The paper of 1878 to which reference has more than once been made<sup>1</sup> describes for the first time the very simple arrangement—a window with two cross-hairs or wires and two pinholes in the frame—by which Galton at first registered the series of photographs to be compounded. For full face one hair was taken horizontally bisecting the pupils and the other, the vertical, bisecting the distance between the pupils. A prick made in each pinhole then registered the photograph. It is requisite that the whole series of photographs should be practically of the same size, or if not, reduced to the same size. All that is needful is, if  $n$  seconds be the correct exposure and there be  $m$  photographs, to give  $n/m$  seconds to each. If we suppose  $n = 50$  and  $m = 8$ , we combine eight portraits. If we wish to combine more, it is better to combine composites of 8 to 10 each to obtain the full composite. Of this Galton writes :

“Those of its outlines are sharpest and darkest that are common to the largest number of the components ; the purely individual peculiarities leave little or no visible trace. The latter being necessarily disposed on both sides of the average, the outline of the composite is the average of all the components<sup>2</sup>. It is a band and not a fine line, because the outlines of the components are seldom exactly superimposed. The band will be darkest in its middle whenever the component portraits have the same general type of features, and its breadth, or amount of the blur, will measure the tendency of the components to deviate from the common type. This is so, for the very same reason that the shot-marks on a target are more thickly disposed near the bull’s-eye than away from it, and in a greater degree as the marksmen are more skilful. All that has been said of the outlines is equally true as regards the shadows ; the result being that the composite represents an averaged figure, whose lineaments have been softly drawn. The eyes come out with appropriate distinctness, owing to the mechanical conditions under which the components were hung.

A composite portrait represents the picture that would rise before the mind’s eye of a man who had the gift of pictorial imagination in an exalted degree. But the imaginative power even of the highest artists is far from precise, and is so apt to be biased by special cases that may have struck their fancies, that no two artists agree in any of their typical forms. The merit of the photographic composite is its mechanical precision, being subject to no errors beyond those incidental to all photographic productions.” (p. 134.)

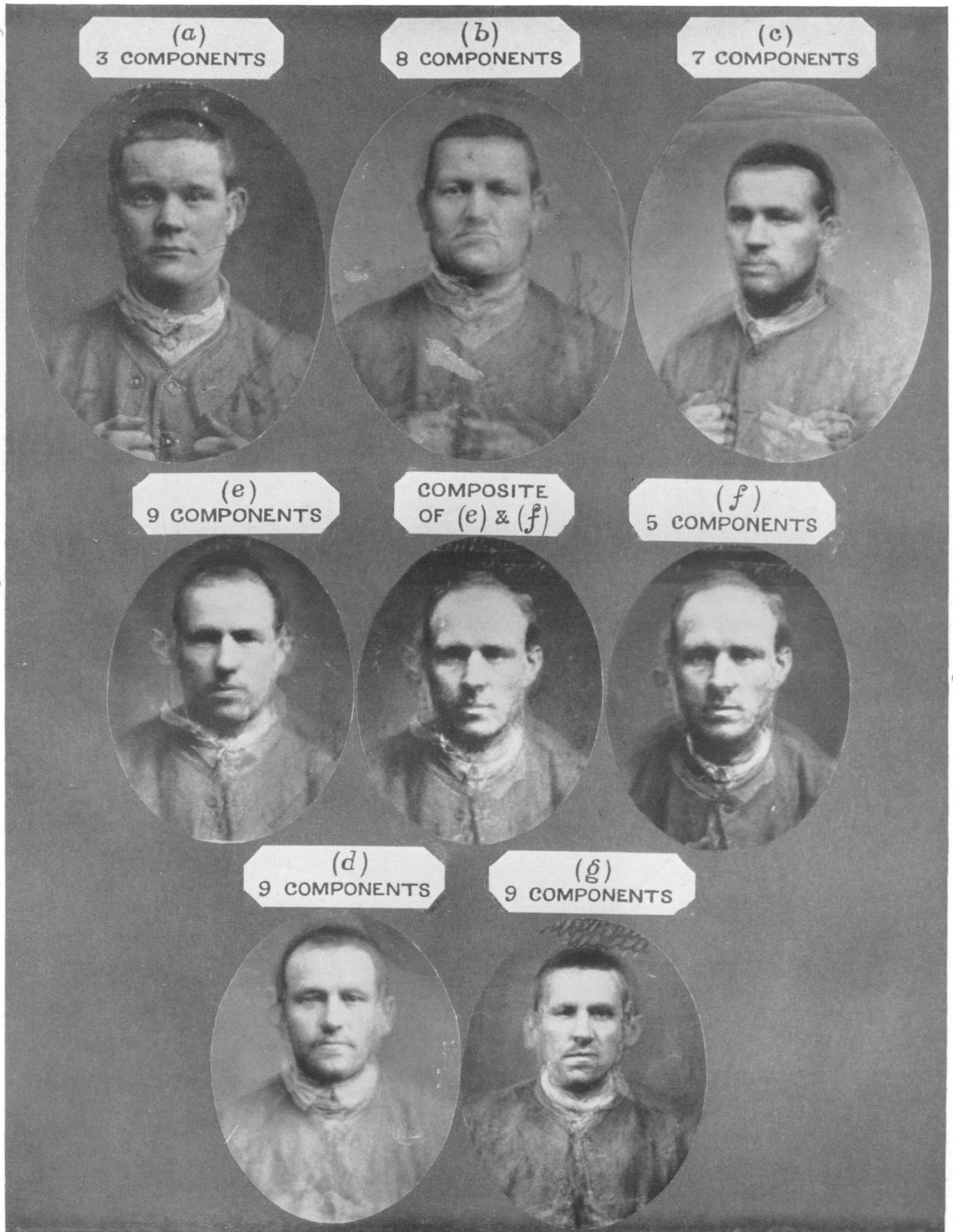
Galton exhibited at the meeting composites of criminals, and notes of them that the special villainous irregularities have disappeared and the common humanity that underlies them has prevailed<sup>3</sup>. This I think should have been used as an argument that the criminal is not a distinct *physical* type, criminality is a mentality and the physical and the mental are not closely correlated. On the other hand, when composite photography is applied to a physically differentiated race, e.g. the Jews, it does in a marked manner indicate a type<sup>4</sup>. And therein, I think, its future usefulness lies.

<sup>1</sup> “Composite Portraits,” *Journal of the Anthropological Institute*, Vol. VIII, pp. 132–42, 1878.

<sup>2</sup> Galton recognised later that this early composite was an “aggregation” rather than an average.

<sup>3</sup> Mr Hyde Clarke in the discussion which followed asserted that the criminal characteristics were eliminated, and they had a natural type of man instead, and attributed the result to the process producing merely an ‘average,’ instead of arguing that there was not a distinct physical criminal type.

<sup>4</sup> See our pp. 293–4 and Plates XXVIII and XXIX.



Composites, made from Portraits of Criminals convicted of Murder, Manslaughter or Crimes of Violence.

COMPOSITES

5 COMPONENTS



7 COMPONENTS



4 COMPONENTS



2 COMPONENTS



PREVALENT TYPES OF FEATURES AMONG MEN CONVICTED OF LARCENY (WITHOUT VIOLENCE)

5 OFFICERS



12 OFFICERS



11 PRIVATES



30 PRIVATES



NORMAL POPULATION. OFFICERS & MEN OF ROYAL ENGINEERS

Comparison of Criminal and Normal Populations.

In the next section Galton records various methods he had hit upon for superposing images. Thus

(a) He had used a sextant with its telescope attached.

(b) Strips of mirror at various angles, their several reflections being simultaneously viewed through a telescope.

(c) A piece of glass inclined at a very acute angle to the line of sight and a mirror beyond it also inclined but in the opposite direction to the piece of glass; the latter must be thin, a selected piece of the best glass used for covering microscopic specimens. Several such pieces inclined at different angles may be used for multiple compounding.

(d) A divided lens like two stereoscopic lenses brought close together in front of the object-glass of a telescope (see our p. 285).

(e) Glass negatives in separate magic lanterns all converging on the same screen.

(f) A camera with a long focus and many slightly divergent object-glasses, each throwing an image of a separate glass negative upon a screen (cf. our p. 285).

(g) A double image prism of Iceland spar.

Of this Galton says (p. 138):

“The best instrument I have as yet contrived and used for optical superimposition is a ‘double-image prism’ of Iceland spar. The latest I have had.....has a clear aperture of a square half an inch in the side, and when held at right angles to the line of sight will separate ordinary and extraordinary images to the amount of two inches, when the object viewed is held at seventeen inches from the eye. This is quite sufficient for working with *carte-de-visite* portraits. One image is quite achromatic, the other shows a little colour. The divergence may be varied and adjusted by inclining the prism to the line of sight. By its means the ordinary image of one component is thrown upon the extraordinary image of the other, and the composite may be viewed by the naked eye, or through a lens of long focus, or through an opera-glass (a telescope is not so good) fitted with a sufficiently long draw tube to see an object at that short distance with distinctness. Portraits of somewhat different sizes may be combined by placing the larger one farther from the eye, and a long face may be fitted to a short one by inclining and foreshortening the former. The slight fault of focus thereby occasioned produces little or no sensible ill-effect on the appearance of the composite. The front and profile faces of two living persons sitting side by side, or one behind the other, can be easily superimposed by a double-image prism.”

The apparatus itself with accessories is figured and described in Galton's paper, and remains after more than thirty years intact to this day in the Galton Laboratory<sup>1</sup>.

Galton remarks that the truth of the composite photograph can be assured by the substantial agreement between the results from different batches of components—“a perfect test of truth in all statistical conclusions.” He tried changing the order of exposure of the components and found substantial identity<sup>2</sup> (p. 135).

<sup>1</sup> There are in fact two such Iceland spar compounders.

<sup>2</sup> It might seem that this point wanted greater experimental demonstration than the short series Galton speaks of. I have, however, Galton's evidence before me; he took three portraits, *A*, *B*, *C*, and compounded *A + B* and *B + A*, the composites are practically identical; then he took *A + B + C*, *A + C + B*, *B + A + C*, *B + C + A*, *C + A + B* and *C + B + A*, and again the composites are practically identical. He had thus good evidence that order of exposure did not

The paper finally discusses the uses to which composite portraiture may be put. Galton refers to :

(i) Typical pictures of different races of men (see our pp. 290, 293-4, and Plate XXXIV).

(ii) Selection of some strongly marked type within a race, e.g. Criminal or Phthisical subjects (see our pp. 286, 291-2 and Plates XXVIII, XXIX and XXXIV).

(iii) Composite portrait of the same individual to obtain more than a single momentary expression. Galton considered that such a composite would have 'varied suggestiveness.'

(iv) Composites from independent portraits of historical personages. It may be from coins, medals or busts. Thus Galton later did Alexander the Great, Napoleon, Cleopatra, etc. (see our p. 295 and Plates XXXVI—XLIV).

(v) Composite portraits of ancestry and collaterals, each individual being given his or her relative 'weight' in terms of exposure. Galton thus hoped to produce 'family types,' and to forecast the physical appearance of the offspring of proposed marriages (see our Plates XXXI and XXXII).

(vi) In the same manner as (v) composite portraits might be produced to aid breeders of pedigree stock to judge the result of any proposed union better than they are able to do at present (see our Plate XXX). Galton took the opportunity of appealing for family portraits taken in the same attitude,  $\frac{4}{10}$  inch or say 10 mm. between the interpupillary line and the line that separates the lips, in *right* profile, full face, and three-quarters always showing the left side, "in this the outer edge of the right eyelid will be only just in sight." I repeat these suggestions of Galton in case any of my readers wish to make experiments in this somewhat difficult art for themselves.

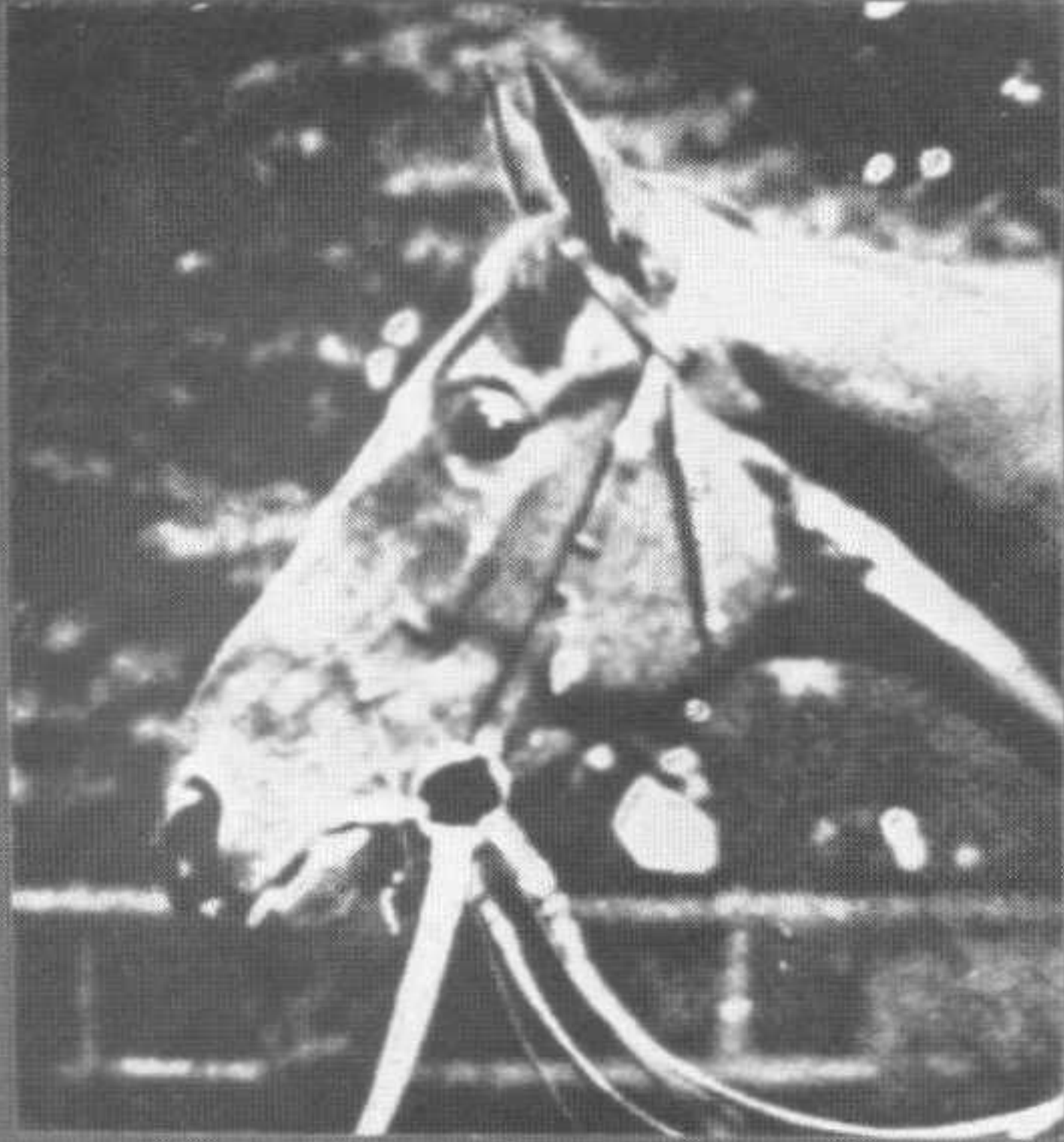
At the York meeting of the British Association, *Trans. B. A.* 1881, p. 3, Galton read a paper "On the Application of Composite Portraiture to Anthropological purposes." He exhibited the first cranial composite, the profile of the Andamanese skull based on eight components (see our Plate XXXIII). The large original composite is still in the *Galtoniana*, but although it is distinctly better than much later work—which has tended to discredit composite portraiture in craniology—I venture to think that from the standpoint of the profile better fiduciary lines might be selected.

The next paper with which we have to deal is that of 1881, in which year Galton gave an account of "Composite Portraiture" to the Photographic Society<sup>1</sup>. Four years had produced great changes and improvements not only in Galton's methods, but in his apparatus. He now figures and describes a much more elaborate instrument not only for compounding, but at the same time for reducing individual transparencies to a standard size. He not only makes the interpupillary line and its vertical bisector the same weight the different components. He also demonstrated that the effect of an exposure for  $n$  seconds was sensibly the same whether it was continuous or given in  $p$  equal doses; the experimental prints giving intensity of tint due to exposure for a variety of values of  $p$  have survived to this day.

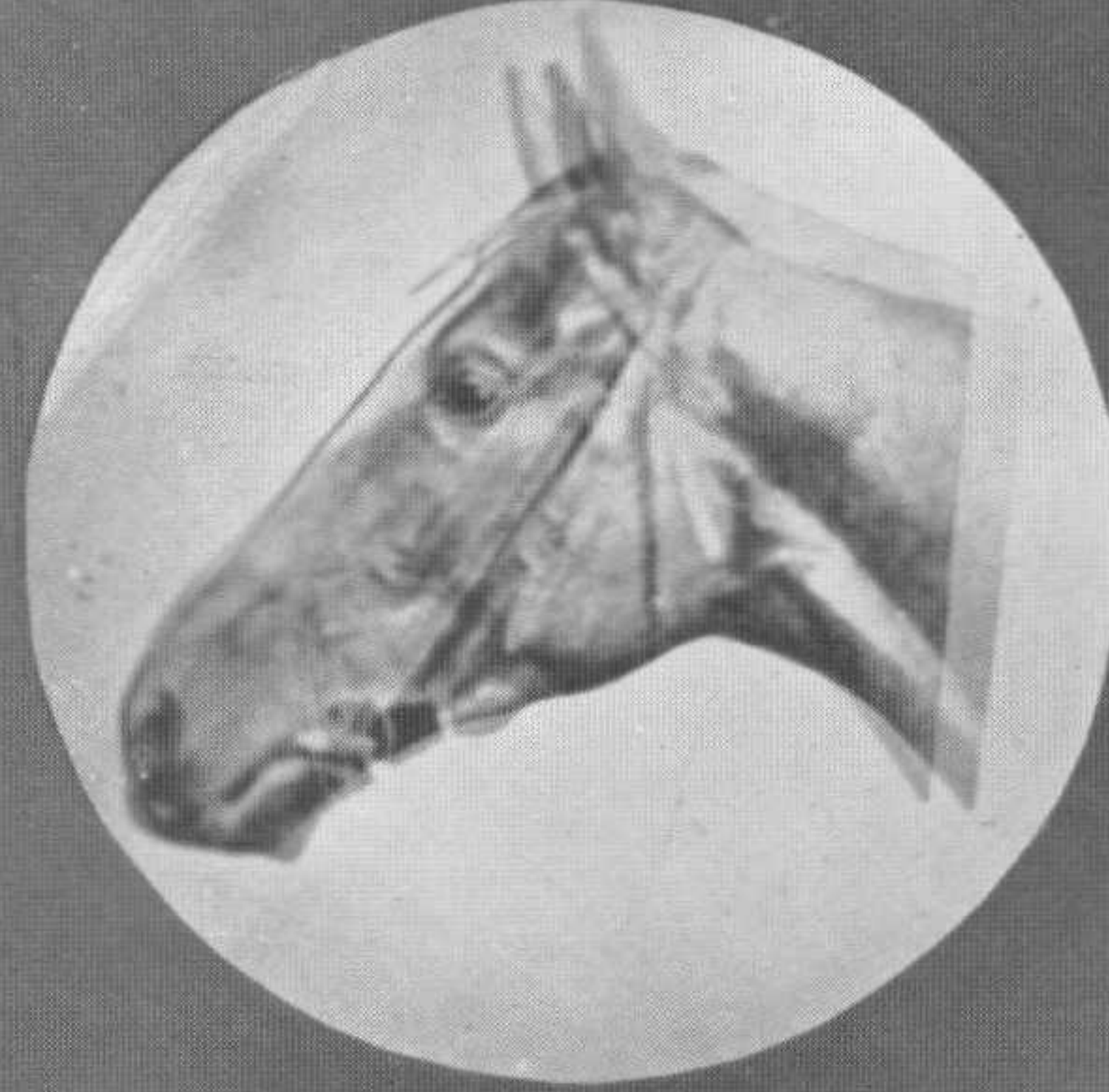
<sup>1</sup> *Journal and Transactions of the Photographic Society of Great Britain*, Vol. v. pp. 140-46, June 14, 1881.



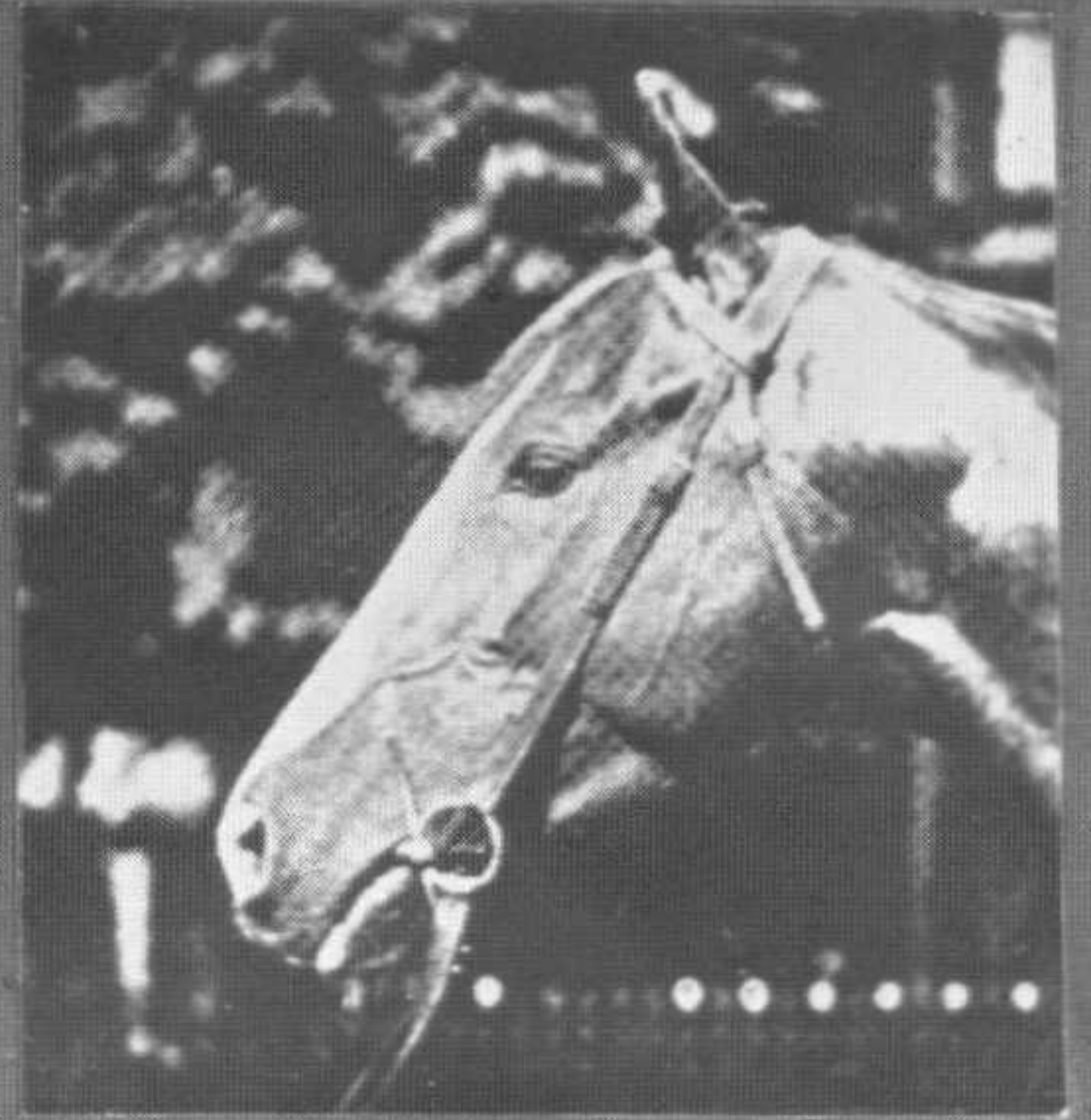
a - "Sir Visito"



x = a + b



b - "Solaro"



y = c + d



c - "Raconteur"



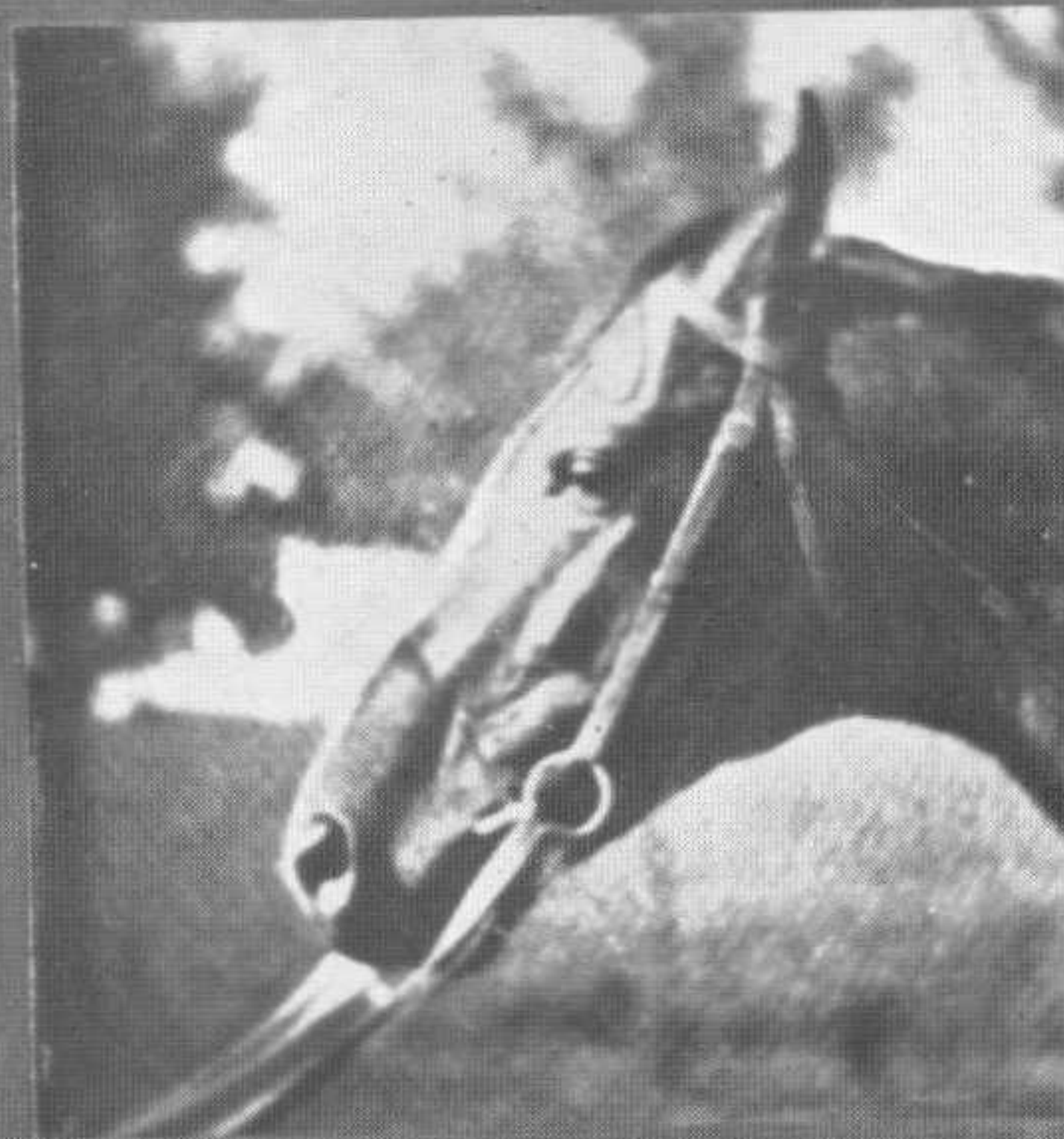
d - "St. Marrock"



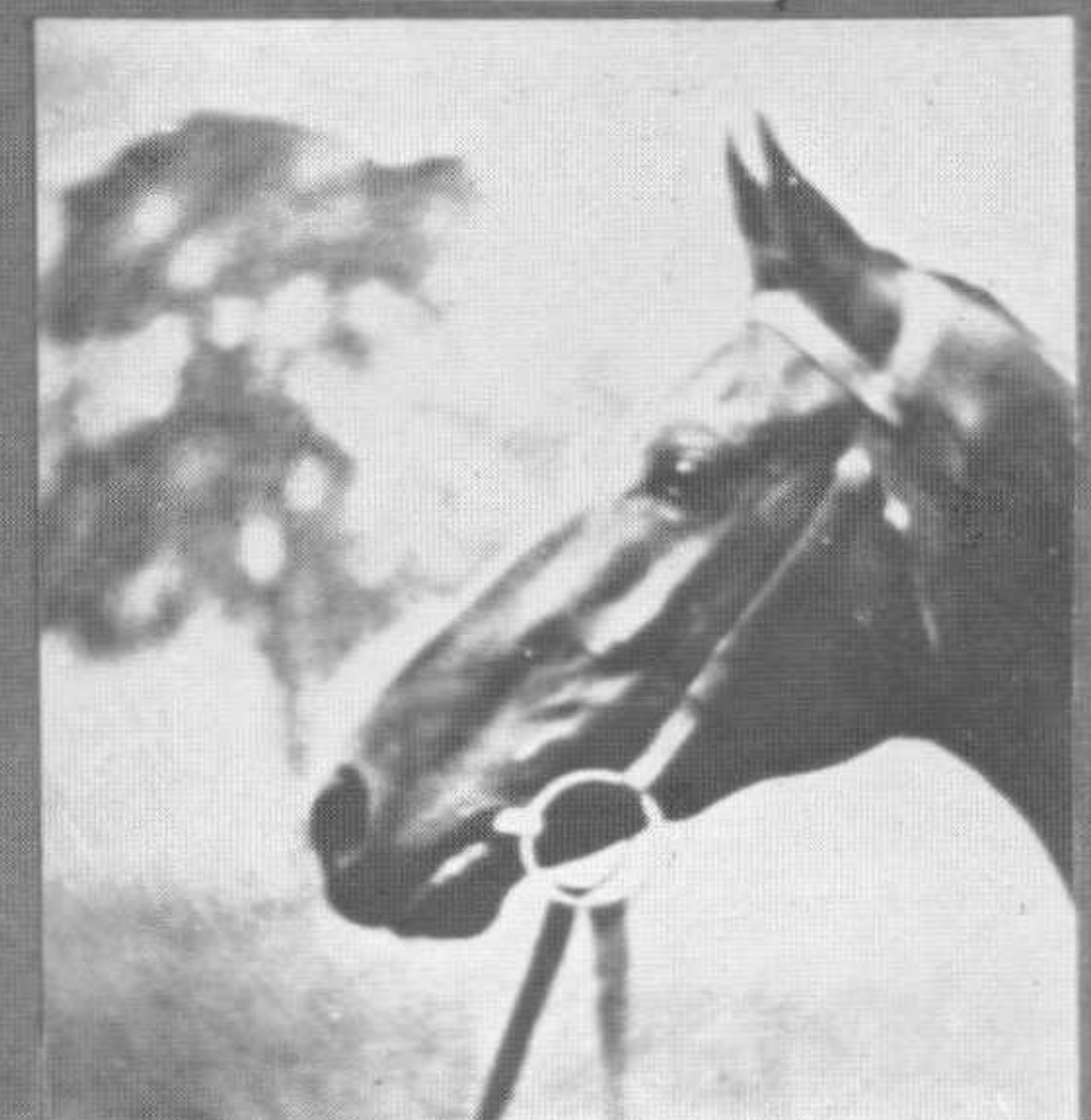
z = e + f



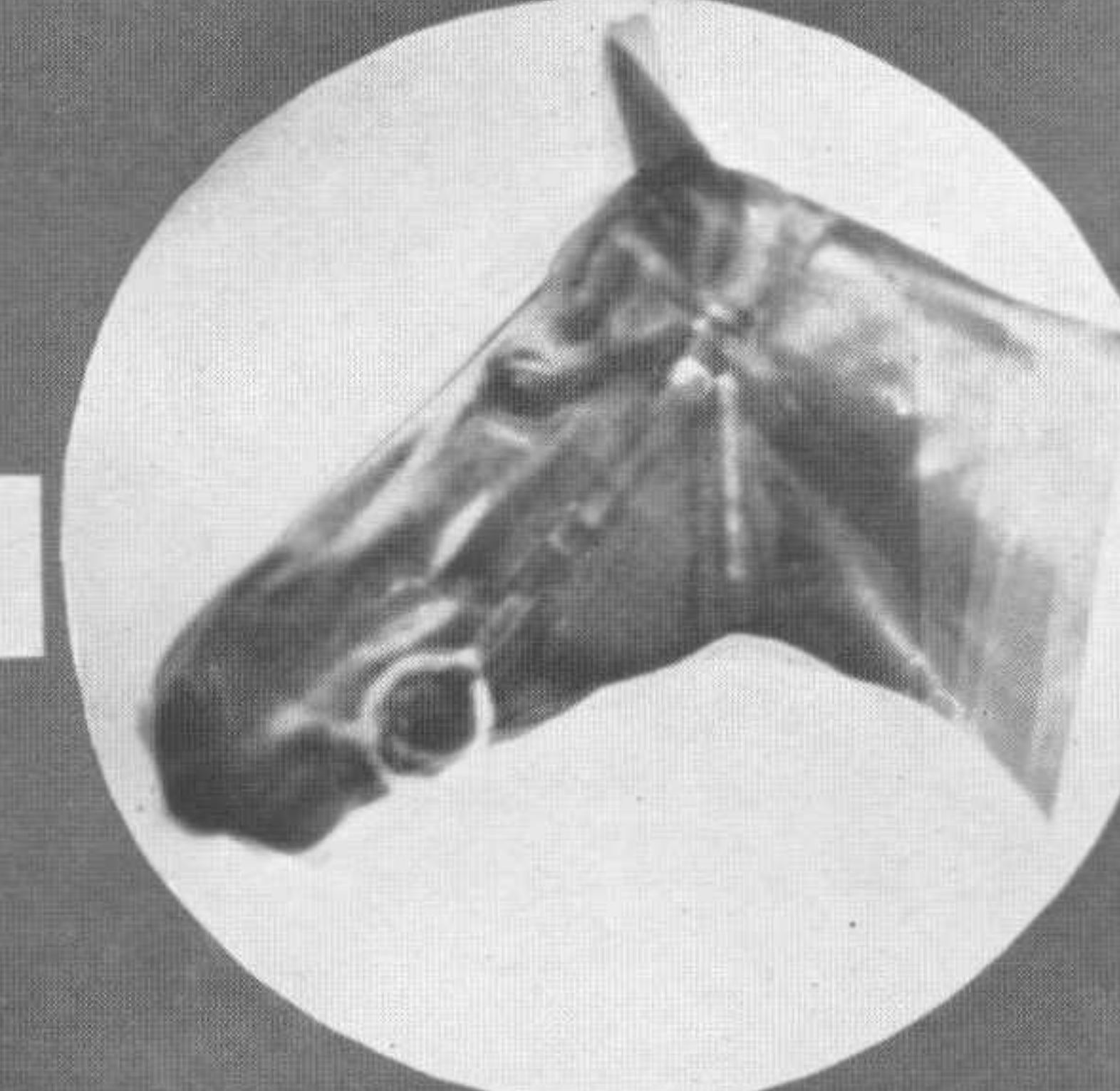
e - "Speedwell"



f - "Salebeia"



COMPOSITE OF a TO f



COMPOSITES OF

THOROUGHBREDS

FULL FACE



COMPOSITES



PROFILE



Portraits of three Sisters, full face and profile, with the corresponding Composites.

FATHER, MOTHER & THREE DAUGHTERS



FATHER, MOTHER, ONE SON & TWO DAUGHTERS



3 SISTERS, FULL FACE & PROFILE



FATHER, MOTHER & TWO DAUGHTERS



6 WELSH MINISTERS



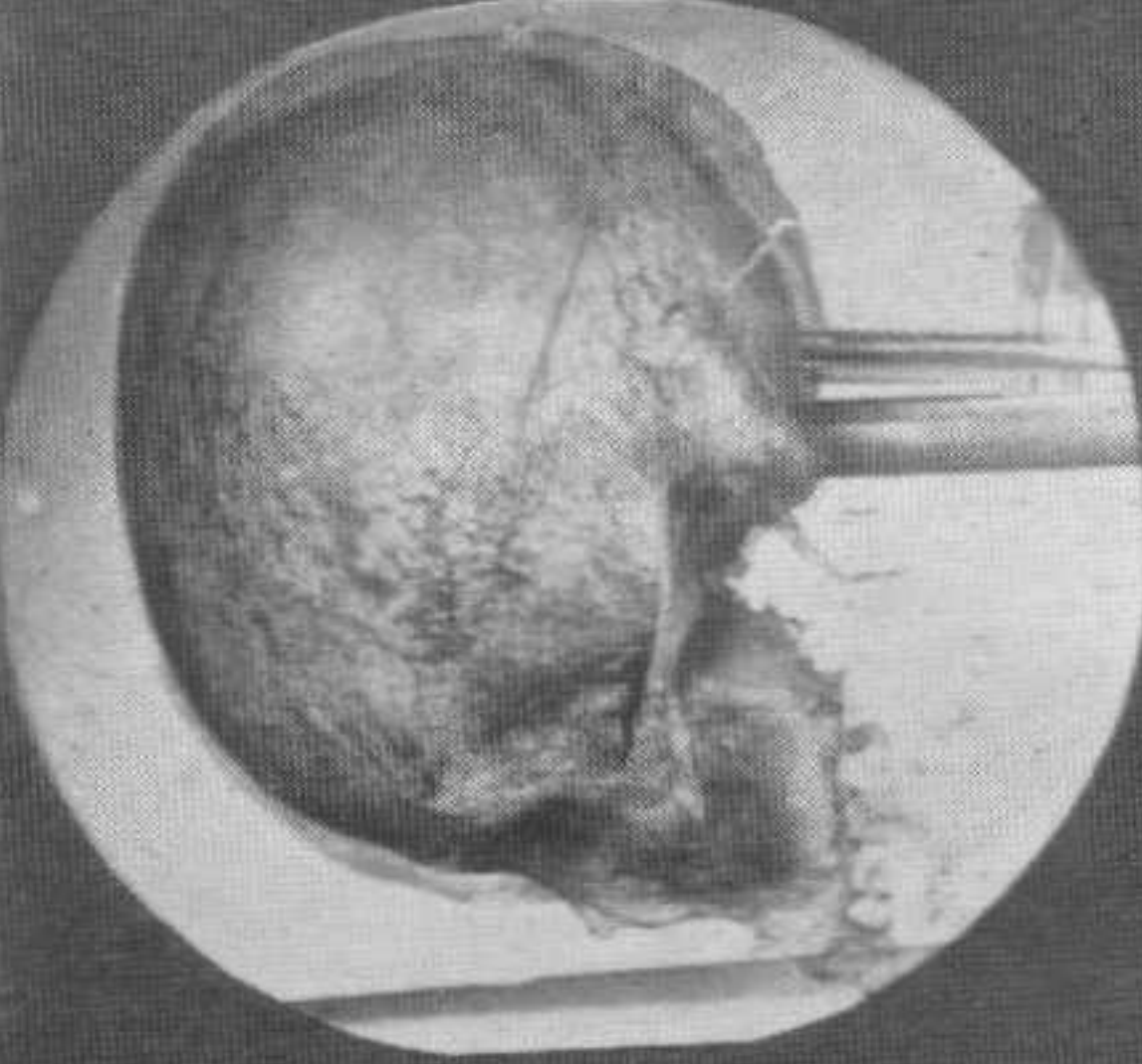
COMPOSITES OF CHILDREN



COMPOSITES OF YOUNG ADULTS



EARLIEST SKULL COMPOSITE



FATHER, SON & DAUGHTER



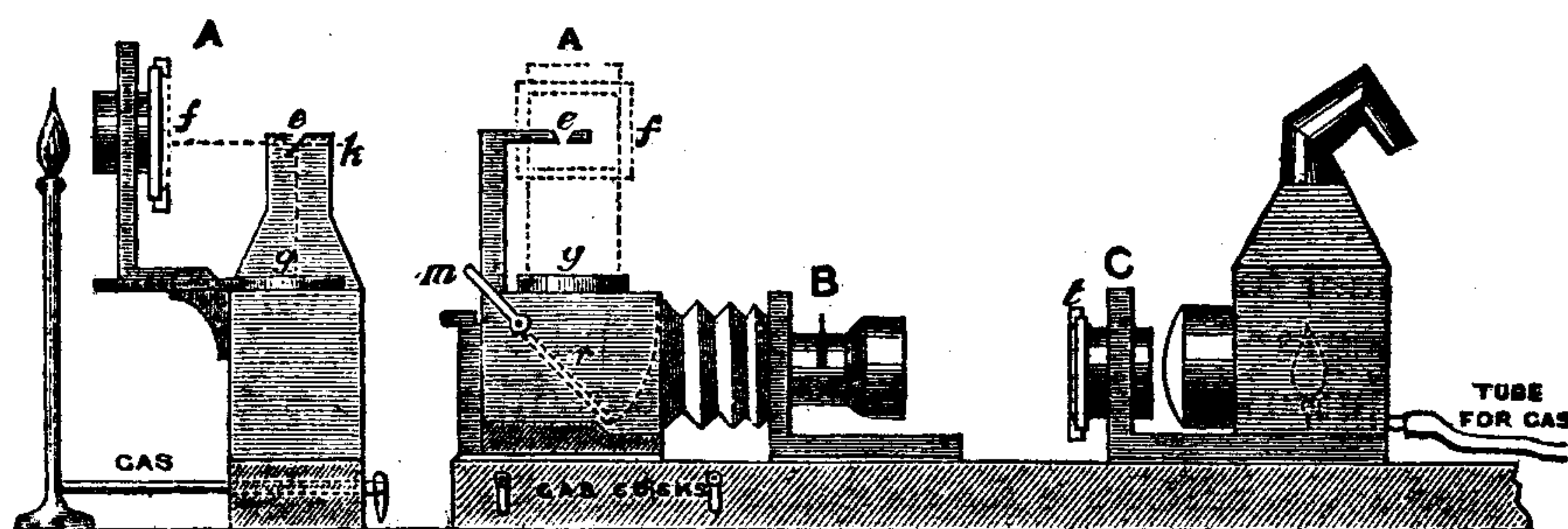
COMPOSITE OF SIBLINGS



OMNIBUS PLATE OF COMPOSITES

for all subjects, but the distance from interpupillary line to the line of the lips is also made constant<sup>1</sup>. The general principle of the apparatus is that of a modified copying-camera, only the alteration in scale and the adjustment in position are not done on the focusing-screen, because it is desirable that the negative which is to be several times exposed should remain fixed in position. By the simple artifice of a mirror let down at 45° across the camera, Galton gets an image on a horizontal screen in the roof of his camera, and upon this screen also are thrown the three fiducial lines which serve as register-marks for his adjustments. The details of the apparatus will be sufficiently indicated by the accompanying line engraving and Galton's description of it; we may merely remark that gas would now-a-days be probably replaced by electric light. The apparatus is still preserved in the Galton Laboratory.

DIAGRAM SHOWING THE ESSENTIAL PARTS.



- |   |   |
|---|---|
| <p><b>A</b> The body of the camera, which is fixed.</p> <p><b>B</b> Lens on a carriage, which can be moved to and fro.</p> <p><b>C</b> Frame for the transparency, on a carriage that also supports the lantern; the whole can be moved to and fro.</p> <p><i>r</i> The reflector inside the camera.</p> <p><i>m</i> The arm outside the camera attached to the axis of the reflector; by moving it, the reflector can be moved up or down.</p> <p><i>g</i> A ground-glass screen on the roof, which receives the image when the reflector is turned down, as in the diagram.</p> | <p><i>e</i> The eye-hole through which the image is viewed on <i>g</i>; a thin piece of glass immediately below <i>e</i> reflects the illuminated fiducial lines in the transparency at <i>f</i>, and gives them the appearance of lying upon <i>g</i>—the distances <i>fk</i> and <i>gk</i> being made equal, the angle <i>fk g</i> being made a right angle, and the plane of the thin piece of glass being made to bisect <i>fk g</i>.</p> <p><i>f</i> Framework, adjustable, holding the transparency with the fiducial lines on it.</p> <p><i>t</i> Framework, adjustable, holding the transparency of the portrait.</p> |
|---|---|

Diagram ii.

“For success and speed in making composites, the apparatus should be solidly made, chiefly of metal, and all the adjustments ought to work smoothly and accurately. Good composites cannot be made without very careful adjustment in scale and position. An offhand way of working produced nothing but failures.” (p. 143.)

Galton exhibited certain results of very considerable interest tending to meet criticisms which had been raised. He drew on a square card a circle of about 2.5 inches diameter with a vertical and a horizontal diameter. Where these diameters met the circle he placed four circular discs of different tints, and in one quadrant he placed a black dot. He then made a composite

<sup>1</sup> It would probably be possible by a slight rotation of the frame for the transparency about a central vertical axis to make the interpupillary distance (or the external ocular distance) constant without in any way injuring the result.

of the axial four positions of this card and found: (i) a sharply defined cross, showing the accuracy of adjustment, (ii) four very faint dots one in each quadrant, indicating that any single irregularity hardly survives, (iii) the equal tint of the four dots showing the equality of the exposure, (iv) the uniformity of the resulting tint of the four 'wafers' arising from the exposure of the tinted discs, *A, B, C, D*, in the four orders, *ADCB, BADC, CBAD*, and *DCBA*, demonstrating that order of exposure is not material.

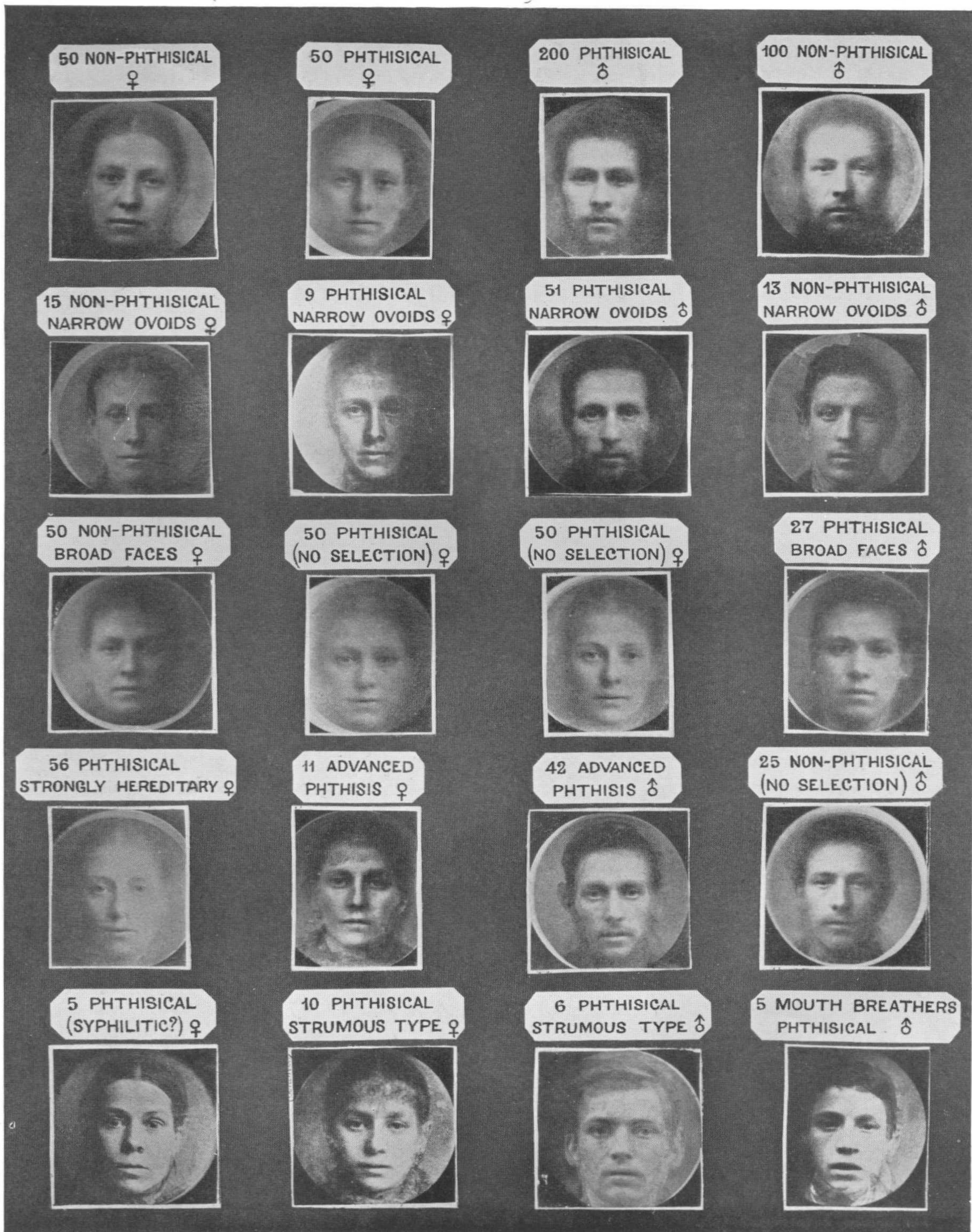
He also showed composites in one of which a portrait *X* was exposed  $\frac{2}{3}$  and a portrait *Y*  $\frac{1}{3}$  of the total exposure, and in the other *X* was exposed  $\frac{1}{3}$  and *Y*  $\frac{2}{3}$  of the total. The individuality of *X* predominated in the first and that of *Y* in the second; thus justifying 'weighting' by length of exposure.

He further exhibited composite portraits of male and female phthisical subjects, and of men and of officers of the Royal Engineers (see our pp. 291–3 and Plates XXIX and XXXIV), and he suggested that with 'artistic touching' beautifully idealised family portraits might be produced for commercial purposes; the irregularities of the individual disappearing. The paper as a whole marks a very considerable development both in the theory and practice of composite portraiture<sup>1</sup>.

We now come to two papers of 1882 and 1885 dealing respectively with composite photographs of phthisical subjects and of Jews. In the first Galton worked in conjunction with Dr F. A. Mahomed, in the second Mr Joseph

<sup>1</sup> It was, perhaps, a misfortune for composite photography, that while it required really extraordinary care and patience, it was very easy to compound in an inferior manner. It became popular, especially in America, and a good deal was published which is of small scientific value and in which no attempt was made at real analysis of the results. Thus *Science* published May 8, 1885, composite portraits of American (*a*) Mathematicians, (*b*) Naturalists, (*c*) Academicians and (*d*) Field Geologists, which lead us hardly further than the conclusions that all American scientists of those days were hairy, and that mathematicians while being least so had more frown. Composites of Washington in three aspects (*Science*, Dec. 11, 1885) are somewhat more successful: *Science* also published (on May 7, 1886) composites of American Indians, but the components were few in number. Further composite photographs were made of undergraduates and graduates of various American Colleges (Jastrow, 1887, did 21 Johns Hopkins doctors of philosophy for the years 1886–7: *Century*, March, 1887. The latter also contains a fairly successful family composite of father, mother, five sons and one daughter). A possibly more scientific use of composite photography was that by Persifor Frazer (*American Philosophical Society*, Vol. xxiii, pp. 433–41, 1888 and *Franklin Institute Journal*, Feb. 1886, p. 123) to obtain an average signature. He illustrates it by one of George Washington, and thinks the process could be used to determine the maximum deviation compatible with a non-forged result. In our own country Arthur Thomson in 1884 (*Journal of Anatomy*, Vol. xix, p. 109) tried to apply it to obtain type Australian and European crania; the components being too few, and the superposition not very satisfactory, the results are not to be taken as condemning the application of the method in craniometry. The possibilities of composite photography in this matter had been referred to by Galton at the 1881 York meeting of the British Association: see *Transactions*, p. 690. Whipple adopted the process for the reduction of meteorological observations (*Quarterly Journal of Meteorological Society*, Vol. ix, p. 189), and it can clearly be employed in harmonic analysis. There is no doubt that Galton's idea was taken up by many, but it may be doubted whether any one but the originator appreciated the amount of care and patience required to produce a good composite. At the same time I cannot pass over the fact that in the *Galtoniana* there exists a splendid series (not by Galton) of racial composites, Wends and Saxons; they are probably of German origin. I am unaware if they have been published.

PLATE XXXIV



Composites of Phthisical and Non-phthisical Hospital Populations.

Jacobs gave him help. The first paper is entitled: "An Inquiry into the Physiognomy of Phthisis by the Method of Composite Portraiture<sup>1</sup>." It contains illustrations of 47 composites and of 113 individual portraits. There is thus a great wealth of material to judge by. Unfortunately, and probably unavoidably, the portraits are all small, the individual smaller than the composite portraits, and this, I venture to think, lessens the accuracy of judgments based on comparisons of this illustrative material.

The question raised by Mahomed and Galton was whether there was any justification for a belief in a phthisical diathesis; it is of course clear that such may exist without involving a phthisical physiognomy. It is further possible that if such a physiognomy exists, it might be produced by the action of the disease itself. The material consisted of 261 male and 181 female photographs of phthisical subjects between 15 and 45 years of age taken partly at Guy's Hospital and partly at the Brompton and the Victoria Park Hospitals for Diseases of the Chest. A schedule for each subject dealt with: Age—extent of disease (advanced, moderate, slight)—duration of disease (chronic, over 3 years; medium, 1 to 3 years; brief, under 1 year)—hereditary taint (strong, some, none)—onset of disease (insidious, or preceded by severe hæmoptysis, bronchitis, pneumonia, pleurisy, syphilis, gout, alcoholism). These classifications enabled composites<sup>2</sup> of various groups to be made. As control two series of female patients, each fifty in number, and a series of male patients 100 in number, all suffering from diseases *other than phthisis*, were taken without selection.

When all individual phthisical patients were compounded without selection, a composite was obtained strikingly like the composite portrait of the non-phthisical: see our Plate XXXIV. If there be made selections of the narrow, ovoid or 'tubercular' faces from the phthisical and non-phthisical patients, or again of broad faces with coarser features from the two groups, we again reach composites closely resembling each other. In other words both phthisical and non-phthisical patients contained representatives of the same two types. Further, of the non-phthisical women 15% gave the narrow ovoid face while only 11.6% of patients with phthisis presented it. Among males the proportion of narrow ovoids was only 13% in the non-phthisical patients and 19.0% among the phthisical on the best estimation. Taken altogether the phthisical cases showed 14.3% and the other than phthisical 14.0% of the narrow ovoid or so-called 'tubercular' physiognomy. The 'tubercular' physiognomy is therefore not more common among the phthisical than the non-phthisical diseased population. Mahomed and Galton write:

"Let us here emphasise the fact that we are now comparing phthisis with *other diseases*, and not with the healthy population, and these observations would seem to show that a delicate person may fail in many ways besides being phthisical, and that a delicate narrow ovoid face may mean liability to other diseases not necessarily tubercular." (p. 13.)

<sup>1</sup> *Guy's Hospital Reports*, Vol. xxv, February, 1882.

<sup>2</sup> In this paper a compound of composites is termed a *co-composite*, and if several co-composites are compounded the result is termed a *co-co-composite*. Composites and co-co-composites are positives, and require to be reversed before printing from them.

When the individuals with a markedly hereditary taint were taken the resultant face had distinctly more delicate features, but the composite seems to the present writer too faint to provide much information; further, these cases may well have shown on the average more emphasised emaciation. On the other hand, if a composite be formed of the far-advanced cases, where the emaciation is shown in the deeply sunken eye, the hollow cheeks, and thinly covered lower jaw, the face was not by any means of the narrow ovoid type. The authors do not state whether the chronic cases were more frequent in the hereditary and the rapid cases in the latter group. Possibly they might have gone further in compounding the material on the basis of the schedule data, but we must remember that the composite photographer has not only a temptation to compound the well-fitting faces, but that to do so is almost a mechanical necessity. As our authors put it:

“We would also draw attention to the fact that this is the first attempt at applying the new process of composite portraiture on a large scale<sup>1</sup>, and that many technical difficulties, mechanical and others, could only gradually be overcome.” (p. 18).

Mahomed and Galton conclude finally that their results

“lend no countenance to the belief that any special type of face predominates among phthisical patients, nor to the generally entertained opinion that the narrow ovoid or ‘tubercular’ face is more common in phthisis than *among other diseases*. Whether it is more common than among the rest of the *healthy* population we cannot at present say.

It is true that taking both sexes together we find 14·3 per cent. of faces that may be classed as ‘narrow ovoids<sup>2</sup>,’ and 9·3 per cent. that come under the head of ‘broad faces with coarse features<sup>3</sup>,’ making in all 23·6 per cent. of our cases which may be grouped under one or other extreme departure in either direction from the normal average; but we doubt if this is more than would be found among the general population. Our results are therefore negative, but it may be they are no less valuable; although we commenced our investigations with the expectation of establishing a ‘type’ on a firm foundation, we shall be little less satisfied with them if they have succeeded in refuting an error.

Although these conclusions would seem to indicate that there is no foundation for the belief that persons possessing certain physical characters are especially liable to tubercular disease, yet it may hereafter be proved that some explanation of the doctrine may be found in the course of the disease when it attacks such persons.” (p. 18.)

In the last paragraph our authors seem to have made an unallowable extension of their result. Were it true, we must totally deny the existence of any hereditary tendency to phthisis. Such, in my opinion, cannot be accepted in view of existing statistical data. Yet any hereditary tendency must depend upon a differentiation in physical structure, for that ultimately is what determines the efficient working of the various bodily organs. But it is idle in the present state of our knowledge to assume that there is a high correlation between the dynamical efficiency of the bodily organs and the physiognomy in particular. It is possible that nasal shape and carriage of the mouth might have some—probably not very intense—correlation with a tubercular diathesis. But no special study of mouth and nose was

<sup>1</sup> When we note that composites of 50 to 200 components were made for the first time, we can appreciate the magnitude of the task.

<sup>2</sup> What our authors term the ‘tubercular’ type.

<sup>3</sup> What they term the ‘strumous’ type.



made in this paper, and it may be doubted whether it could be made on portraits of so small size and all reduced to the same standard length from interpupillary line to lip line.

The main achievement of the paper lies undoubtedly in its demonstration (i) that mechanical difficulties of compounding large series of portraits had been overcome, and (ii) that no marked association exists between a phthisical tendency and physiognomy. The belief that it does exist probably arises from the more emphatic impression on the observer produced by emaciation in the narrow ovoid face.

The second paper to which I have referred is entitled "Photographic Composites<sup>1</sup>," and is remarkable for the two plates of the Jewish type in profile and full face. While many will criticise, and I think rightly criticise, the analysis Mr Jacobs gives of the 'Jewishness' in these portraits, they must agree with him in appreciating the extraordinary fidelity with which they portray Jewish physiognomy, or rather youthful Jewish physiognomy, for we are dealing with young Jews. Mr Jacobs writes :

"But words fail one most grievously in trying to split up into its elements that most living of all things, human expression<sup>2</sup>; and Mr Galton's composites say in a glance more than the most skilful physiognomist could express in many pages. 'The best definition,' said the old logicians, 'is pointing with a finger' (*demonstratio optima definitio*); and the composites here given will doubtless form for a long time the best available definition of the Jewish expression and the Jewish type." (p. 268.)

There is little doubt that Galton's Jewish type formed a landmark in composite photography, and its success was, I think, almost entirely due to (a) increased facility in the process, and (b) to the fact that his composites were based on physiognomically like constituents. In the case of criminality and phthisis he had based his composites on mentally and pathologically differentiated components, and had expected to find mental and pathological characters highly correlated with the facial. His negative results were undoubtedly of value, but they cannot appeal to the man in the street like his positive success with the Jewish type. We all know the Jewish boy, and Galton's portraiture brings him before us in a way that only a great work of art could equal—scarcely excel, for the artist would only idealise from *one* model.

Plate XXXV (described over page) reproduces Galton's Jewish composites. The original photographs are in the Galton Laboratory.

<sup>1</sup> *The Photographic News*, Vol. xxix, April 17 and 24, 1885. The Jewish profile occurs with the earlier, the full face with the later issue. Galton's paper occupied pp. 243-45 of the earlier issue. In the later issue is a paper by W. E. Debenham on Galton's "Composite Portraits" (pp. 259-60), which does not seem to do more than repeat, probably unconsciously, certain methods already referred to by Galton (see our pp. 285, 287), except in the one matter of acquiring the stereoscopic power without any instrument. There is also a paper entitled: "The Jewish Type, and Galton's Composite Photographs," by Joseph Jacobs (pp. 268-9).

<sup>2</sup> Mr Jacobs here uses "expression" not like Darwin in the kinematic sense, but in the statical sense of physiognomy.

## PLATE XXXV, Left (Profile).

*b* is the composite of five portraits of young Jewish boys; and similarly *c* is the composite of five others. *d* is a co-composite of *b* and *c* reversed in position, and thus represents all the ten components. *a* is a composite of five other older faces; the components of *b* and *c* are given in Galton's original plates.

## PLATE XXXV, Right (Full Face).

*f* is the composite of the five full-faced portraits corresponding to *b*, while *g* is the composite of those corresponding to *c*. *h* is a co-composite of *f* and *g*, and represents therefore all ten components. *e* is a composite of the five older faces. The influence of a black curl on the forehead of *f*<sub>1</sub> can be traced in *f*, and even in *h*, where it is reversed (or as in *f*<sub>1</sub>).

The great bulk of Galton's own paper in the earlier issue deals with modifications and improvements of his technique, and should be consulted even to-day by any would-be compounder. His final advice with regard to composite photography may be cited :

"It must be borne in mind by those who attempt it, that offhand methods will not avail. The adjustments must be made with judgment and extreme care to produce good effects. The difference between a very carefully-made composite and one that has been combined with only moderate care is great." (p. 245.)

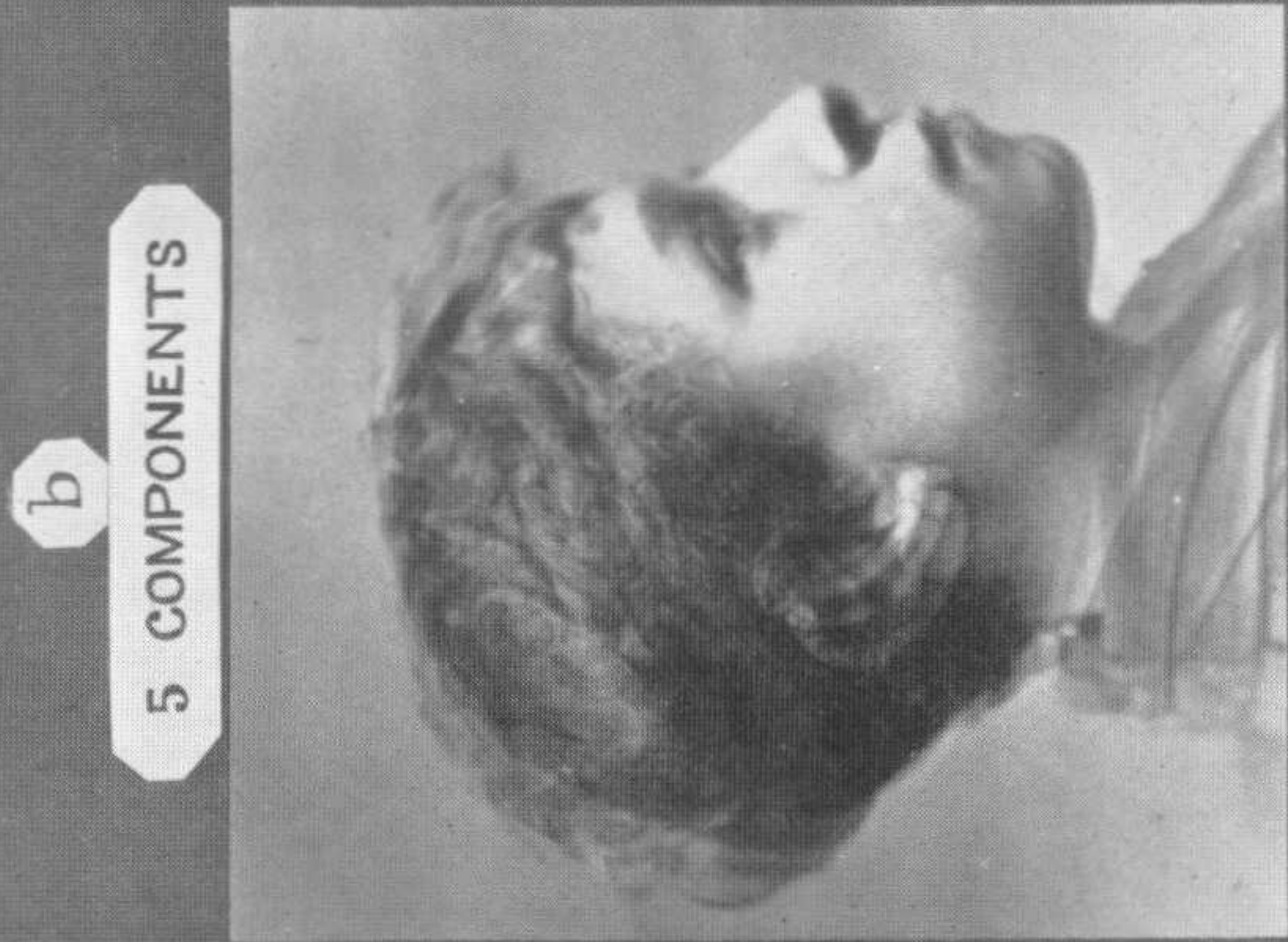
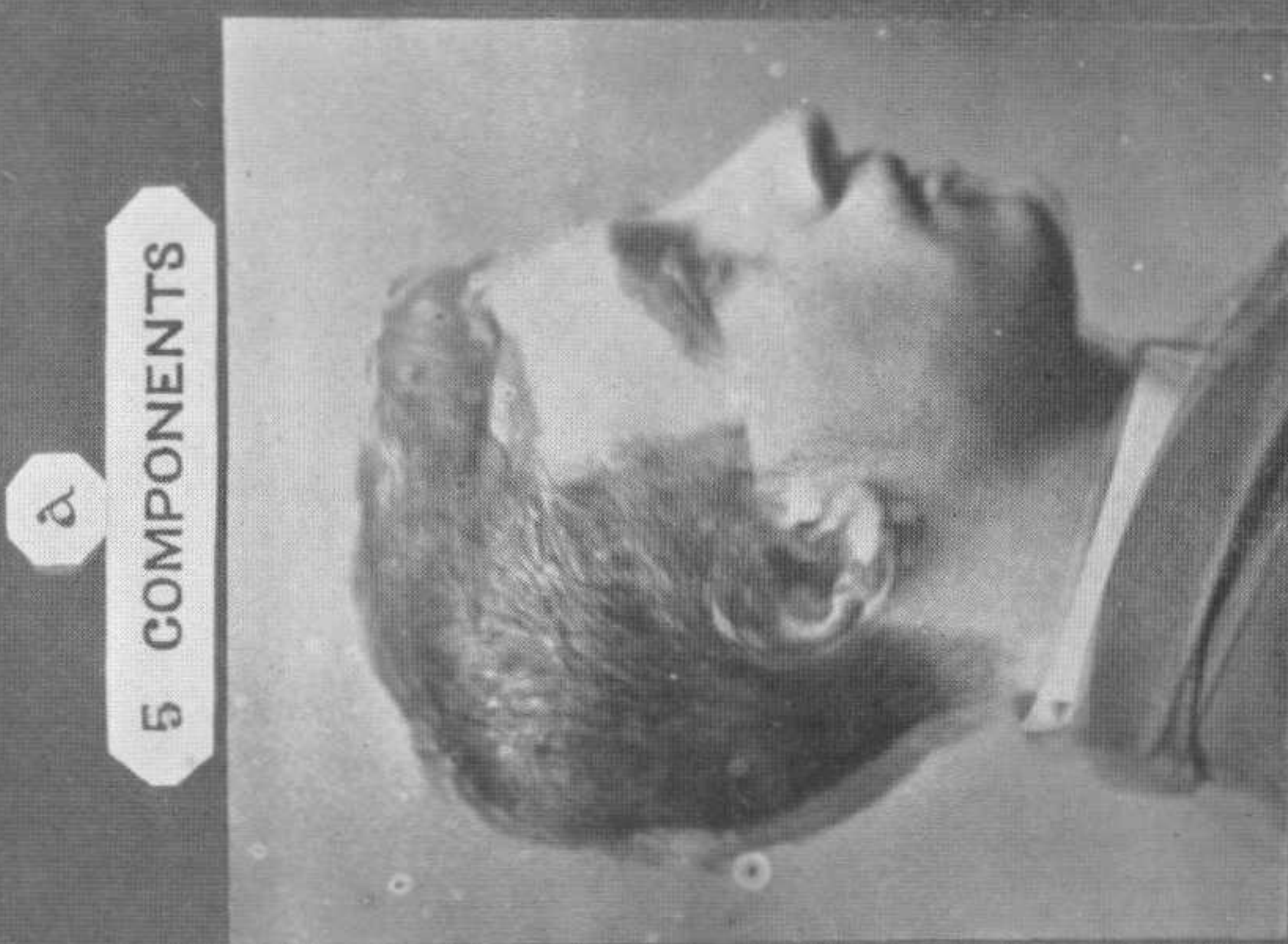
In the paper Galton also gives for the first time his fiducial system for profiles; it consists of a sloping straight line with two horizontal straight lines proceeding from it to the right. The portrait is adjusted so that this sloping straight line touches the forehead, and passes through what the photographer estimates to be the alveolar point, i.e. the point of the gum between the middle incisors of the upper jaw<sup>1</sup>. The horizontal lines are then taken to bisect the pupil and to coincide as far as possible with the lip line respectively. Galton further notices that if he brings one of the fundamental points *A* of his fiducial system on to the marked optical axis of his instrument, and makes the corresponding point *A'* of his image agree with *A*, then throughout all further adjustments *A* will coincide with *A'*, and this will much simplify the complete adjusting. Beautiful as Galton considered the adjustments of his own compounding camera to be, he believed great improvements might be made in it, especially in the direction of automatically setting the component in position after taking a series of measurements upon it. He further emphasised the need of a simple optical method of combining a considerable number of photographs to test what the compound would be like before actually photographing a composite.

The success of the 'Jewish type' convinced Galton that the future of composite photography lay largely in ethnological and genetic work. He refers in this matter to the typical crania of different races prepared by Dr Billings, Surgeon-General of the U.S. War Department<sup>2</sup>, Mr A. Thomson of the Edinburgh Medical School (see our p. 290 *ftn.*), and earlier by himself, using composite photography. But he clearly placed less stress on this than on purely ethnographic portraiture of the living.

In 1879 Galton gave a Friday evening lecture at the Royal Institution

<sup>1</sup> The alveolar point is a well-recognised craniometric point, and it seems slightly better in this respect to use it than to make with Galton the sloping fiducial line touch the upper gum between the mid-incisors. It might even avoid the difficulties of the superciliary ridges in adult males to take the fiducial line from nasion to alveolar point.

<sup>2</sup> Copies of these are to be found in the Galton Laboratory.



The Jewish Type.

Profile.

Full Face.

on composite portraiture<sup>1</sup>. The lecture is called "Generic Images," according to what Galton terms "the happy phrase of Professor Huxley."

"The word generic presupposes a genus, that is to say, a collection of individuals who have much in common, and among whom medium characteristics are very much more frequent than extreme ones. The same idea is sometimes expressed by the word typical, which was much used by Quetelet, who was the first to give it a rigorous interpretation, and whose idea of a type lies at the basis of his statistical views. No statistician dreams of combining objects into the same generic group that do not cluster towards a common centre, no more can we compose generic portraits out of heterogeneous elements, for if the attempt be made to do so the result is monstrous and meaningless." (p. 162.)

We thus see that Galton demands a clustering round Quetelet's 'mean man' as a success for a composite portrait; in such a case the mediocre characteristics prevail over extreme ones; the common traits reinforce each other and the extreme ones tend to disappear. In the course of the lecture Galton showed the following composites:

(a) A family portrait of two brothers and a sister. He built this up by the aid of three converging magic lanterns carefully adjusted, and showed that he obtained the same effect as a composite photograph of the three components.

(b) Alexander the Great [6] (reproduced in printed lecture: see our Plates XXXVI and XXXVII).

(c) Antiochus, King of Syria [6] (not hitherto published: see our Plate XXXVIII).

(d) Demetrius Poliorcetes [6] (not hitherto published: see our Plate XXXIX).

(e) Cleopatra [5]. The composite was here as usual better than the components, "none of which gave any indication of her reputed beauty; in fact, her features are not only plain, but to an ordinary English taste are simply hideous" (not hitherto published: see our Plate XL).

(f) Nero [11] (not hitherto published: see our Plate XLI).

(g) Greek female face [5] (not hitherto published: see our Plate XLII).

(h) Roman female face [6] (reproduced in printed lecture: see our Plate XLIII).

(i) Napoleon I [5] (reproduced in printed lecture: see our Plate XLIV).

(j) The English criminal [18] (reproduced in printed lecture). Galton here recognises two types of criminals, one with broad and massive features like Henry VIII, but with a much smaller brain; the other with a weak and certainly not a common English face<sup>2</sup> (see our Plates XXVIII and XXIX).

While Galton exhibited in this lecture more composite portraits than I think he showed on any other occasion, his main object was to compare

<sup>1</sup> *Proceedings of the Royal Institution*, April 25, 1879, Vol. ix, pp. 161-70, with an autotype reproduction of the Roman Lady, Alexander the Great, Napoleon the Great, and the English criminal.

<sup>2</sup> The material on which all these composites were based is still in the Galton Laboratory, although many of the photographs are sadly faded and some of the negatives have perished (owing to the use of poor chemicals, or to inadequate washing). With the exception of the phthisical plate all our reproductions are from the original material.

general impressions of the mind founded upon blended memories with blended portraits. He writes :

“In the pre-scientific stage of every branch of knowledge, the prevalent notions of phenomena are founded upon general impressions; but when that stage is passed and the phenomena are measured and numbered, many of those notions are found to be wrong, even absurdly so. This is the case not only in professional matters, but in those with which everyone has some opportunity of becoming acquainted. Think of the nonsense spoken every day about the signs of coming weather, in connection, for example, with the phases of the moon. Think of the ideas about chance, held by those who are unacquainted with the theory of probabilities; think of the notions on heredity before the days of Darwin. It is unnecessary to multiply instances; the frequent incorrectness of notions derived from general impressions may be assumed, and the object of the following discourse is to point out a principal cause of it.

Attention will be called to a source of error that is inherent in our minds, that vitiates the truth of all our general impressions, and which we can never wholly eliminate except by separating the confused facts upon which our general impressions are founded and treating them numerically by the regular methods of statistics. It is not sufficient to learn that an opinion has been long established or held by many, but we must collect a large number of instances to test that opinion, and numerically compare the successes and failures.” (p. 161.)

Galton assumes the physiological basis of memory to be of the following character :

“Whenever any group of brain-elements has been excited by a sense-impression, it becomes, so to speak, tender, and liable to be easily thrown again into a similar state of excitement. If the new cause of excitement differs from the original one, a memory is the result. Whenever a single cause throws different groups of brain-elements simultaneously into excitement, the result must be a blended memory. We are familiar with the fact that faint memories are very apt to become confused. Thus some picture of mountain and lake in a country which we have never visited often recalls a vague sense of identity with much we have seen elsewhere. Our recollections cannot be disentangled, though general resemblances are recognised. It is also a fact that the memories of persons who have great powers of visualising, that is of seeing well-defined images in the mind's eye, are no less capable of being blended together. Artists are, as a class, possessed of the visualising power in a high degree, and they are at the same time pre-eminently distinguished by their gifts of generalisation. They are of all men the most capable of producing forms that are not copies of any individual, but represent the characteristic features of classes.” (p. 162.)

Galton holds that the brain has the capacity for blending memories together, and that general impressions are faint and perhaps faulty editions of blended memories. Thus there is some analogy between general impressions and composite photographs, both are generic images.

“A generic mental image may be considered to be nothing more than a generic portrait stamped on the brain by the successive impressions made by its component images<sup>1</sup>.”

But while the photographic generic image gives each component a weight proportional to its exposure, Galton says that the mental composite does not give weight in the same manner.

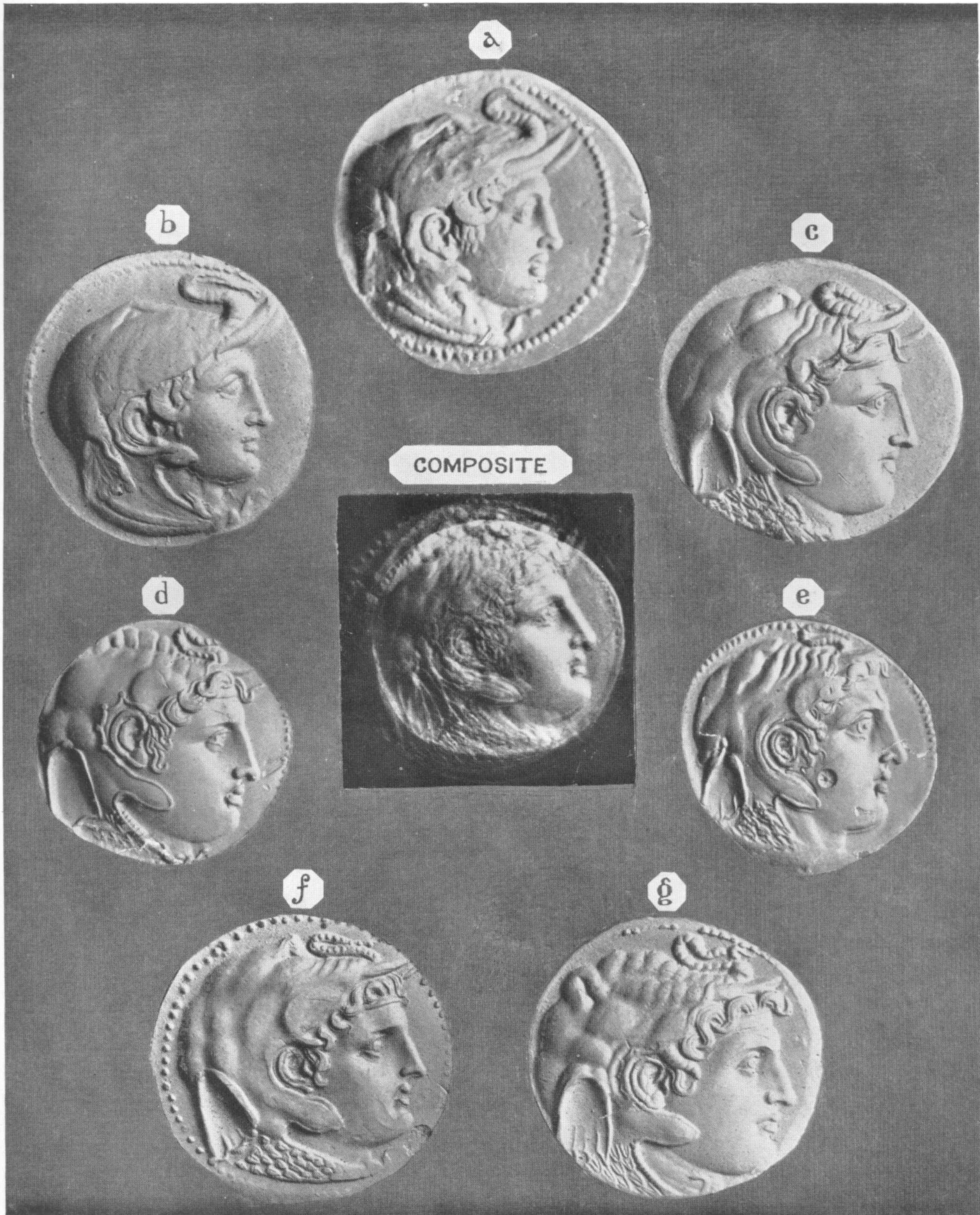
“The physiological effect of prolonged action, or of reiteration, is by no means in direct proportion to the length of the one or to the frequency of the other.”

He then cites the Weber-Fechner Law of the geometrical mean<sup>2</sup> as one at least of the sources of error in general mental impressions.

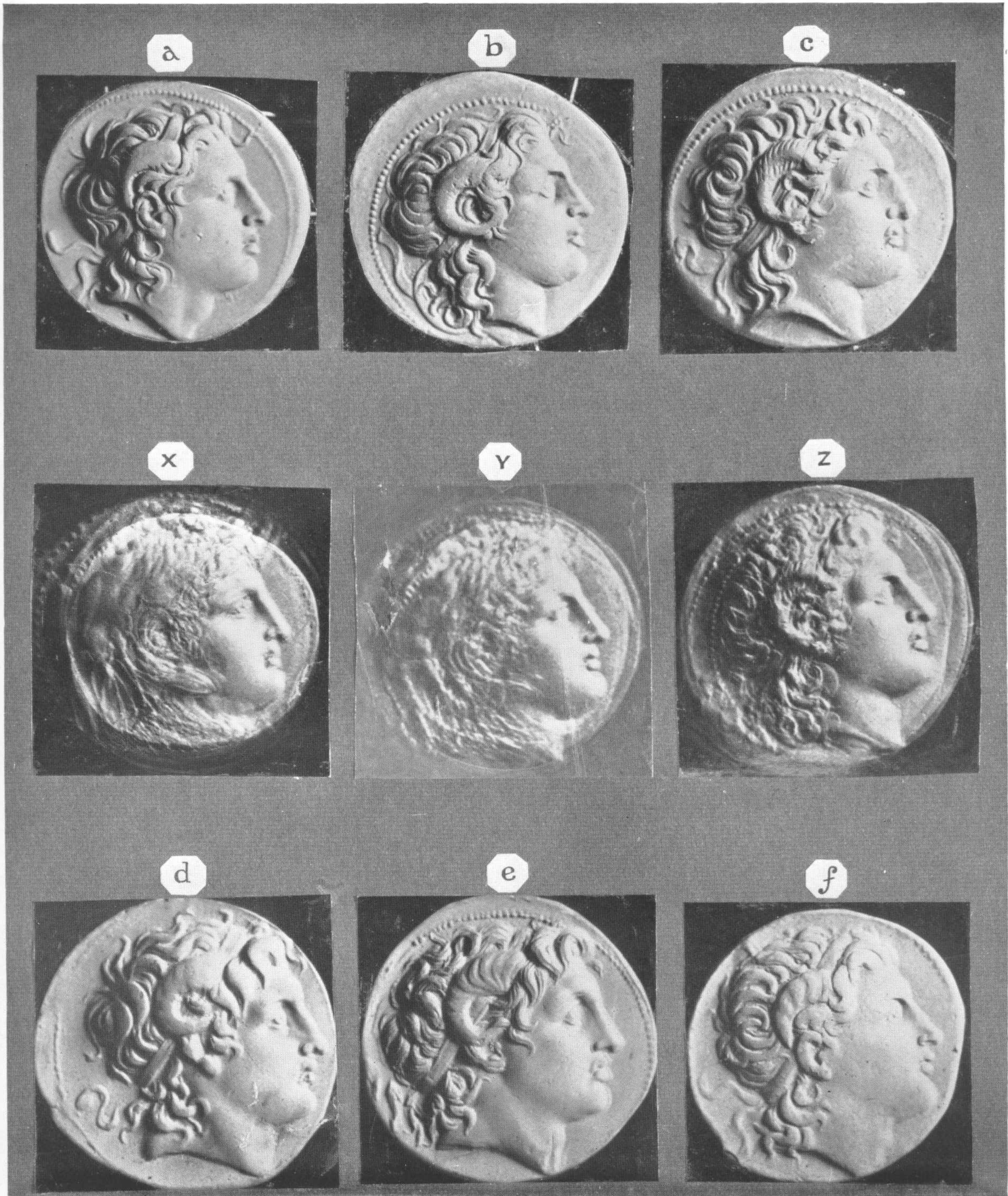
“Exceptional occurrences leave an impression on the brain of far greater strength, and habitual occurrences of far less strength, than their numbers warrant.”

<sup>1</sup> Galton here cites Huxley (*Hume*, p. 95) as independently reaching the same conclusion.

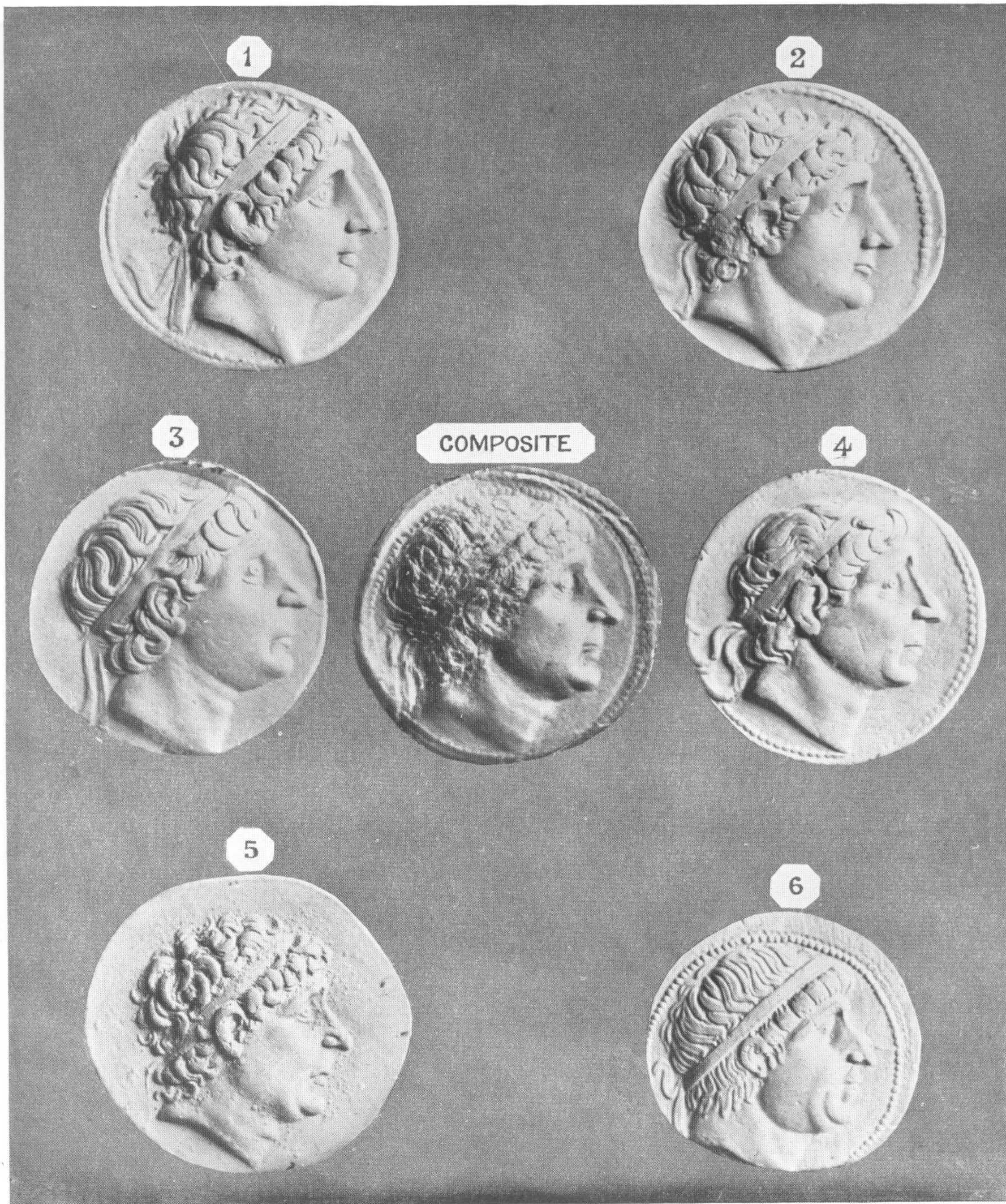
<sup>2</sup> Illustrated in the lecture itself by spinning discs painted black and white in concentric rings, one giving an arithmetical the other a geometrical series of tints; the eye repudiates the former as a graduated scale.



Indian Portraits of Alexander the Great with Composite in centre.

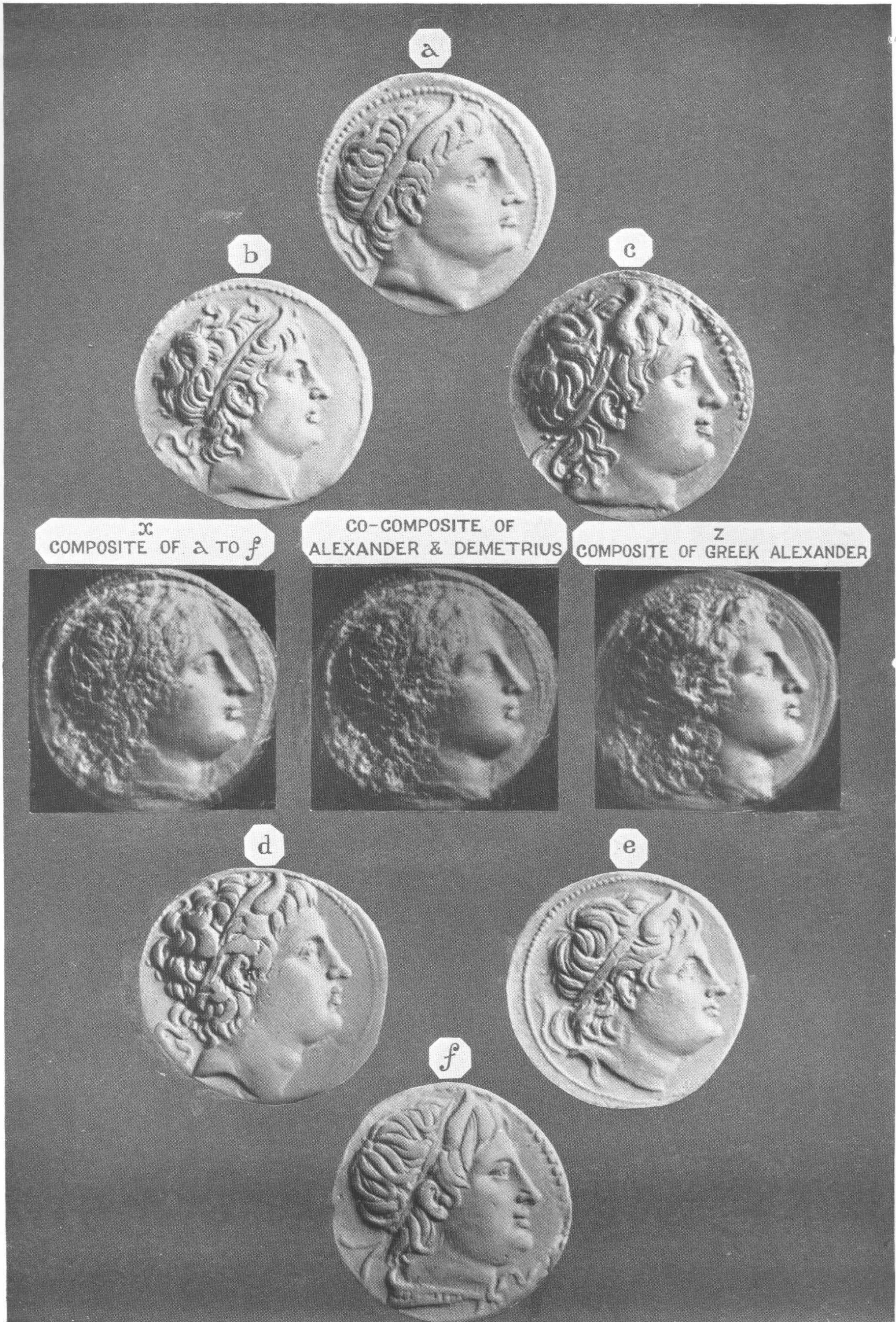


*a to f*, Portraits of Alexander the Great on coins of Lysimachus, King of Thrace.  
*X* = Composite of Indian Alexander (see Plate XXXVI).  
*Z* = Composite of *a to f*.  
*Y* = Co-composite of Indian and Greek Portraits.

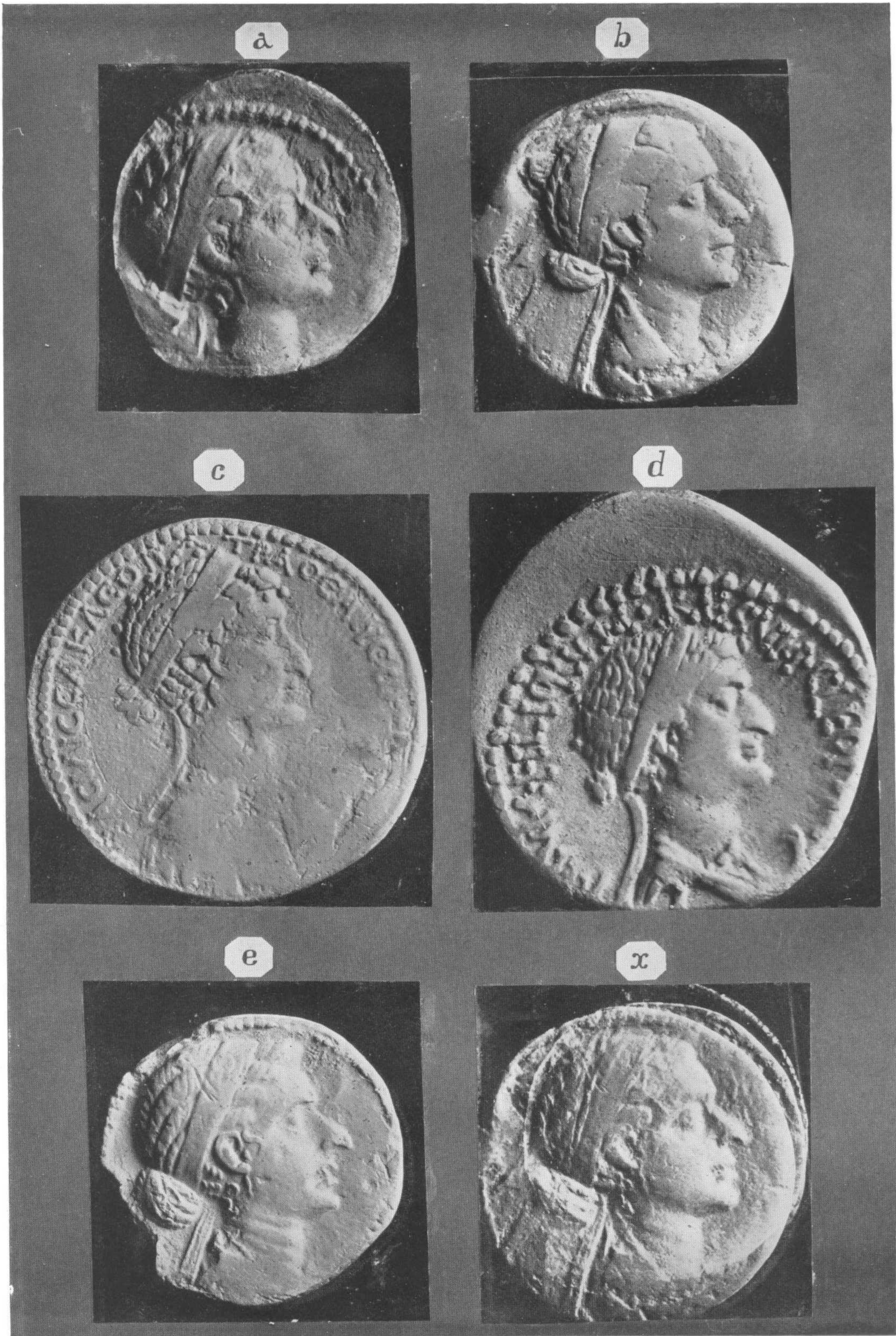


Six Portraits of Antiochus I, King of Syria, arranged in order of date with Composite in centre.





Six Portraits of Demetrius Poliorcetes, King of Macedonia, *a* to *f*, giving typical Greek Head.



Five Portraits of Cleopatra, Queen of Egypt, *a* to *e*, with Composite *x*.



12 PORTRAITS OF NERO, EMPEROR OF ROME.  
WITH COMPOSITE.

a-Philistis, Queen of Sicily



b-Arsinoe, wife of Ptolemy II



c-Berenice, wife of Ptolemy III



COMPOSITE



d-Arsinoe, wife of Ptolemy IV



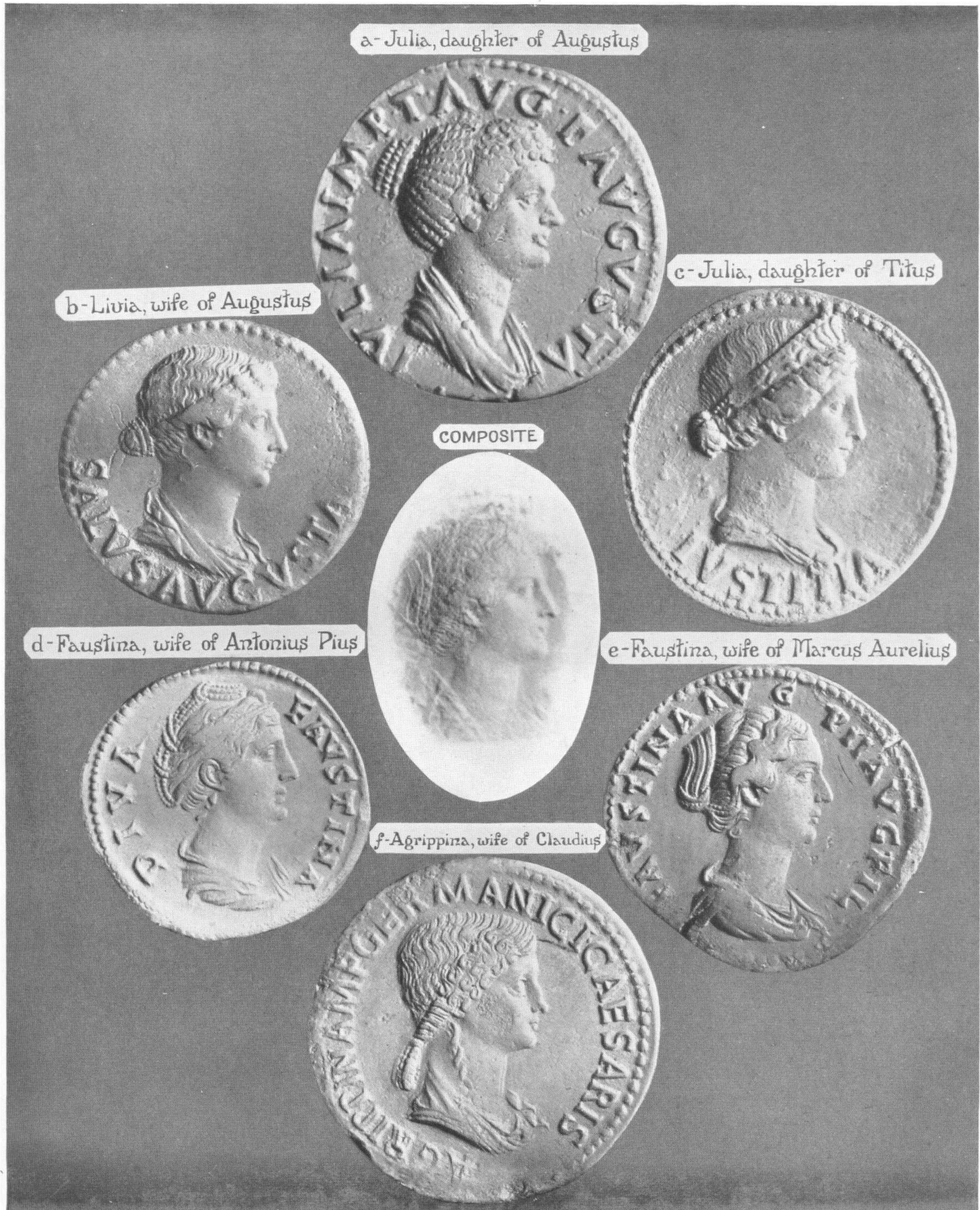
e-Cleopatra, Queen of Syria



f-Phthia, Queen of Epirus



Portraits of Greek Queens with their Composite.



Roman Ladies with Composite.



Six Portraits of Napoleon I with Composites and Co-composite.

Just as in the composite photograph some images may be alien to the genus, so in the case of the mind superficial and fallacious resemblances may be associated.

“Seeing as we easily may, what monstrous composites result from ill-sorted combinations of portraits, and how much nicety of adjustment is required to produce the truest possible generic image, we cannot wonder at the absurd and frequent fallacies in our mental conceptions and general impressions.”

Galton continues:

“Our mental generic composites are rarely defined; they have that blur in excess which photographic composites have in a small degree, and their background is crowded with faint and incongruous imagery. The exceptional effects are not overmastered, as they are in the photographic composites, by the large bulk of ordinary effects. Hence in our general impressions far too great weight is attached to what is strange and marvellous, and experience shows that the minds of children, savages and uneducated persons have always had that tendency. Experience warns us against it, and the scientific man takes care to base his conclusions upon actual numbers.

The human mind is therefore a most imperfect apparatus for the elaboration of general ideas. Compared with those of brutes its powers are marvellous, but for all that they fall vastly short of perfection. The criterion of a perfect mind would lie in its capacity of always creating images of a truly generic kind, deduced from the whole range of its past experiences. General impressions are never to be trusted. Unfortunately when they are of long standing they become fixed rules of life, and assume a prescriptive right not to be questioned. Consequently, those who are not accustomed to original inquiry entertain a hatred and a horror of statistics. They cannot endure the idea of submitting their sacred impressions to cold-blooded verification. But it is the triumph of scientific men to rise superior to such superstitions, to devise tests by which the value of beliefs may be ascertained, and to feel sufficiently masters of themselves to discard contemptuously whatever may be found untrue.” (pp. 168–70.)

The words just cited—almost lost in their manner of publication—are among the finest Galton ever wrote in the service of science.

In reply to the recent inquiry of a friend as to what point I had reached in my account of Galton’s labours, I said: To the discussion of composite portraits in his researches on psychology. It seemed to him an inappropriate association. Yet almost all Galton’s photographic work in his own mind had relation to psychology, and up to the end of his life he continued to develop photographic methods for statistically studying mental characters. From composite portraiture the stage was for him an easy one to generic mental images, thence he passed to the Weber-Fechner Law, and this turned his thoughts to the statistical bearings of the latter as we have already seen. The relation Galton held to exist between generic mental images and composite photographs is well illustrated by Galton’s paper entitled “Generic Images” published in *The Nineteenth Century* for July, 1879<sup>1</sup>. This is in some respects an enlargement of the Royal Institution Lecture, with less technical description and no plate. The point he emphasises in this paper is the bearing of composite portraiture on then current metaphysical conceptions. He writes:

“Composite portraits are, therefore, much more than averages, because they include the features of every individual of whom they are composed. They are pictorial equivalents of those elaborate statistical tables out of which averages are deduced. There cannot be a more perfect example than they afford, of what the metaphysicians mean by generalisations, when the objects generalised are objects of vision, and when they belong to the same typical group, one important characteristic of which is that medium characteristics should be far more

<sup>1</sup> Vol. VI, pp. 157–69. In this paper Galton compares the composite portrait to Quetelet’s “mean man.” (p. 162.)

frequent than divergent ones. It is strange to notice how commonly this conception has been overlooked by metaphysicians, and how positive are their statements that generalisations are impossible, and that the very idea of them is absurd. I will quote the lucid writing of Sir W. Hamilton to this effect, where he epitomises the opinions of other leading metaphysicians. I do so the more readily because I fully concede that there is perfect truth in what he says, where the objects to be generalised are not what a cautious statistician would understand by the word generic. Sir W. Hamilton says (*Lectures*, II, p. 297):

‘Take for example, the term *man*. Here we can call up no notion, no idea corresponding to the universality of the class, or term. This is manifestly impossible. For as *man* involves contradictory attributes and as contradictions cannot exist in one representation, an idea or notion adequate to *man* cannot be realised in thought. The class *man* includes individuals, male and female, white and black and copper coloured, tall and short, fat and thin, straight and crooked, whole and mutilated, etc., and the notion of the class must therefore at once represent all and none of these. It is therefore evident, though the absurdity was maintained by Locke, that we cannot accomplish this; and this being impossible, we cannot represent to ourselves the class *man* by any equivalent notion, or idea.... This opinion, which after Hobbes, has been in this country maintained among others by Berkeley, Hume, Adam Smith, Campbell, and Stewart, appears to me not only true, but self-evident.’”

To this Galton replies, demolishing by a concrete representation an imposing philosophical dogma:

“If Sir W. Hamilton could have seen and examined these composite portraits, and had borne in mind the well-known elements of statistical science, he would certainly have written very differently. No doubt, if what we are supposed to mean by the word *man* is to include women and children and to relate only to their external features and measurements, then the subject is not suitable for a generic picture, other than of a very blurred kind, such as a child might daub with a paint-brush. If, however, we take any one of the principal races of man and confine our portraiture to adult males, or adult females, or to children whose ages lie between moderate limits, we ought to produce a good generic representation.”

Bold indeed to face the metaphysician in his own cave, and assert that his generic pictures were as those of a child daubing with a paint-brush, solely because he had not adequately, i.e. statistically, defined what was to be understood by a genus, and a generalisation! It is the old tale of the scientist, analysing phenomena, coming up against the metaphysician bandying words<sup>1</sup>. No wonder that Galton’s psychology was of small influence with philosophising dialecticians!

### (B) *Photographic Bi-projection, Indexing of Profiles, etc.*

As late as April, 1888, Galton was still thinking over composite photography. In his earlier work he had made the vertical distance between the

<sup>1</sup> My friend Professor W. P. Ker warns me to avoid an *ignoratio elenchi*. It seems to me that any argument would turn on how far the “general idea” is that of a limited class. I feel sure that Berkeley and I think Hamilton would have argued that the abstract idea of a Jewish Boy was impossible. Yet Galton shows that we can form a concrete image of such a Boy, and he sees no reason why we should not, if so constituted, visualise him. Berkeley (*Works*, Vol. I, pp. 76–7, 1843) confesses that what other minds can do, he knows not, but he himself cannot abstract the qualities from a number of individuals and compound them to a general notion. Both Berkeley and Hamilton surveyed their own minds, and they do not appear to have experimented on the visualising faculty of other minds.

What Galton asserts is that it is possible to reach a general idea or a generic image provided the individuals generalised form a limited class or *genus*, and he holds that the metaphysicians, proceeding purely by introspection, had overlooked the statistical criteria for the homogeneity of a group or *genus*.



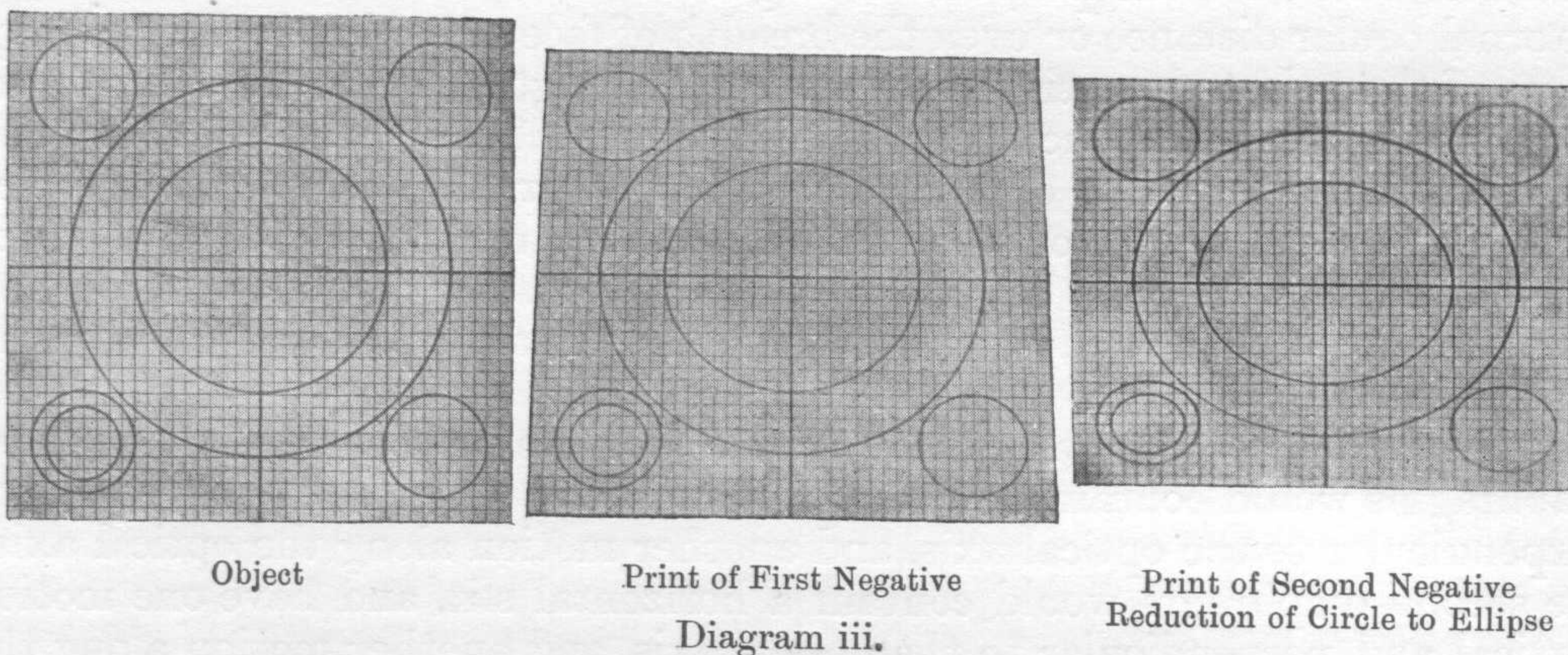
pupillary line and the line of the lips the same for all his components. But the result of this vertical distance only being the same was a great diversity in breadths, leading to an absence of sharpness in the outline; thus, as Galton expressed it<sup>1</sup>, the result was an *aggregate* rather than a *mean*. He now considered that the value of composites would be much increased, if they were at the same time reduced to a common breadth as well as a common vertical standard. Galton chose as his breadth the interpupillary distance, but for some purposes it might be more useful to take, say, the external ocular distance or even the breadth of face at ear level. The average value of the selected vertical and horizontal lengths was to be determined, and each photograph reduced to these dimensions. Thus the problem becomes precisely that referred to on our p. 45. A photographic arrangement which would act as a bi-projector was needful, and one must be devised in which foreshortening would not be accompanied by any sensible blur. Galton first considered that this result could be obtained by a form of pin-hole camera he had seen discussed in the *Photographic News*; namely one in which the pin-hole was replaced by two adjustable diaphragms. The first of these diaphragms would contain a vertical slit, and have a motion horizontally but perpendicular to the optical axis, and another motion along the optical axis; the second diaphragm would contain a horizontal slit, and have one motion vertical and perpendicular to the optical axis, and another motion along the optical axis. By proper adjustment of the two diaphragms, interchanging them if needful, any desired modifications in height and breadth of the object could be made. Theoretically the scheme is admirable; it is precisely that of the bi-projector referred to on p. 46, first ftn., except that the beam of light is replaced in the latter by a "mechanical straight line." The practical difficulty lies in the need of a very intense light on the object, not only to reduce the long exposure, but to enable the operator to adjust the image on the focal plane. When I discussed with Galton in 1903 the possibility of double photographic reduction, he did not refer to this pin-hole scheme, possibly he had discarded it after trial<sup>2</sup>.

Galton's notebooks and papers show that he spent in that year much time over this problem of reducing photographically a circle to an arbitrary ellipse. He proceeded, however, by an entirely different method. He proposed to rotate his object plane round a vertical axis until it made an angle  $\theta_1$  with the vertical plane, and then photograph it, trusting to stopping down to

<sup>1</sup> *Photographic News*, April 27, 1888.

<sup>2</sup> Trials have recently been made in the Galton Laboratory of this method of bi-projectional photography. To get rid of blurring the slits had to be extremely narrow, and thus a four hours' exposure might be necessary for the reduction of a black and white drawing. It was then found that the negative of the drawing had a series of light and dark bands across it. I am not certain whether these are due to some diffraction effect, or to slight inequalities in the breadth of the slits. I have found that a precisely similar system of bands, of course in one direction only, may arise in photographing the sun with a focal plane shutter, when owing to clearness of atmosphere it is needful to reduce the breadth of the slit in the shutter to a minimum. Another objection to the method is that the circular dots used by draughtsmen for points become ellipses, and vertical and horizontal lines do not remain of the same thickness, but this objection applies to all methods of photographic bi-projection.

cure the blurring. A print was then taken of the result, and this print placed in the objective plane rotated through an angle  $\theta_2$  in the *opposite* direction to  $\theta_1$  is rephotographed. Then Galton discovered that with a certain relation<sup>1</sup> between  $\theta_1$  and  $\theta_2$  the second photographing can be made to restore linearity, or an original circle be converted into an ellipse. The accompanying diagrams indicate the three stages of Galton's process. On the last diagram he had written the words "Show this to Pearson." He never did so and only



after his death has his biographer discovered the large amount of time and energy Galton spent over this matter; there are elaborate tables of  $\theta_1$  and  $\theta_2$  with the corresponding vertical and horizontal reductions. There is also the first draft of a paper intended for publication, but I cannot find that the paper and the tables<sup>2</sup> were ever completed, still less published. Like so many of Galton's ideas it was simple and suggestive, but Galton was too old in

<sup>1</sup> We have found that a single negative will suffice, if a second camera be employed to photograph the image on the focal plane screen of the first, this camera being adjusted so that its focal plane makes an angle  $\theta_2$  with the focal plane of the first camera. The difficulty lies in the length of exposure requisite if the objectives of both cameras are cut down so as to reduce blurring to insignificance. Nothing is gained theoretically or practically by tilting as well as rotating the object plane of the first and the optical axis of the second camera. The theory is as follows: Let  $d_1$  and  $b_1$  be respectively the distances from the optical centre of the first camera to the object plane and to the focal plane, and  $d_2$  and  $b_2$  the distances from the optical centre of the second camera to the focal plane of the first camera and to its own focal plane. Then for rectilinearity in the photograph we must have

$$d_2 \tan \theta_1 = b_1 \sin \theta_2;$$

and if  $R_v$ ,  $R_h$  be the vertical and horizontal scales of reduction, then

$$R_v = d_1 d_2 / (b_1 b_2), \quad R_h = R_v \cos \theta_1 \cos \theta_2.$$

Thus  $R_h$  must be less than  $R_v$ , but this is no limitation as the object can always be turned through a right angle. Actually the chief difficulty lies in the suitable choice of  $d_1$  and  $d_2$ . The apparatus takes a simpler form if we keep the two optic axes in the same straight line, and the object perpendicular to them, but rotate the focal planes in opposite directions.

<sup>2</sup> There is also a bundle entitled "Photographic Reduction in breadth" with models in both wood and card of the proposed camera apparatus. As far as I can see Galton always proposed making an auxiliary intermediate print.

1903 to spend the necessary time in working out the practical details of camera dimensions, or spend the hours required in dark-room experimental work. As in the similar case of analytical photography, what is needed is a young and enthusiastic photographer.

To grasp fully Galton's photographic activities at this time we must bear in mind two important facts. He was still searching for some physical features which should have high association with the mental characters. This attitude was perfectly reasonable at that date, because not only no correlations between such characters had been determined, but the methods of measuring correlations were of the crudest kind. Further Galton was a traveller, and every traveller is accustomed as he passes along to notice that the racial mentality changes with the change of the physical characters. The conception therefore naturally arises that physique and mentality are highly correlated. The American Indian, the Negro, or the Arab has each his individual physique, and each also his individual mentality. But this appearance of high correlation may be most deceptive; it does not follow that there is any organic linkage between the physical and psychical characters. If a race be started from a pair of individuals both possessing a physique of type  $A$  and a mentality of type  $A'$ , we may find in later generations an apparent linkage of  $A$  and  $A'$  in all the members; but this is not a true correlation, and a cross-breeding may show that  $A$  and  $A'$  have no organic relation, and can be at once separated. In the second place Galton did, like most men of his generation and probably like most of us to-day, consciously or unconsciously, give weight to physiognomy. So impressed by physiognomy is mankind in ordinary every-day life, that we hardly realise how much confidence we place in it. We say a person is good or bad, is intelligent or stupid, is slack or energetic, on what is too often only a rapid physiognomic judgment. The custom is so universal as a rough guide to conduct, that we are almost compelled to believe that there is in human beings an intuitive or instinctive appreciation of mental character from facial expression. Galton differed only from the mass of us in desiring to ascertain on what physiognomic appreciation is based. He belonged to a generation in which the influence of Lavater and the belief in some form of phrenology were still appreciable. He accordingly sought to isolate types and to measure deviations from facial type, in order to determine whether facial variations were correlated with mental variations. He was really attempting to make a true science out of the study of physiognomy. The anthropologist up to Galton's date had employed portraiture to distinguish racial types physically. Galton employed portraiture to distinguish if possible between mental types. He may have been pursuing a will-o'-the-wisp, but this psychical investigation was really at the basis of all his photographic work, and he was interested in my desire for a photographic 'bi-projector,' not in the first place because it would relieve the difficulties of an editor, but chiefly because it would be of great service in composite and analytical photography. It may be that it is rather on the *play* of features than on their static form that our intuitive judgment as to mental and moral

character is based<sup>1</sup>. In this case a static photograph would only lead to a negative, albeit important conclusion<sup>2</sup>.

From Galton's outlook on mankind the mentality and physique of its stirps were of first-class importance to the child, and he emphasised the value of a family record made on a standardised plan to the child as early as 1882 (*Fortnightly Review*, January, 1882, pp. 26–31), and of such a record Galton held an essential feature to be a series of photographs.

“Obtain photographs periodically of yourselves and of your children, making it a family custom to do so, because unless driven by some custom the act will be postponed until the opportunity is lost. Let these periodical photographs be full and side views of the face on an adequate scale, and add any others you like, but do not omit these. As the portraits accumulate have collections of them autotyped. Take possession of the original negatives, or have them stored in safe keeping, labelled and easy to get at. They will not fade<sup>3</sup>, and the time may come when they will be valuable for obtaining fresh prints or for enlargement. Keep the prints methodically in a family register, writing by their side all such chronicles as those that used to find a place on the fly-leaf of the family Bibles of past generations, and much more besides. Into the full scope of that additional matter I do not propose now to enter. It is an interesting and important topic that requires detailed explanation, and it is better for the moment not to touch upon it.”

Here we see Galton's thoughts turning in the direction whence afterwards arose his *Record of Family Faculties* and his *Life-History Album*.

“This, however, may be said, that those who care to initiate and carry on a family chronicle, illustrated by abundant photographic portraiture, will produce a work that they and their children and their descendants in more remote generations, will assuredly be grateful for. The family tie has a real as well as a sentimental significance. The world is beginning to perceive that the life of each individual is in some real sense a prolongation of those of his ancestry. His character, his vigour and his diseases are principally theirs; sometimes his faculties are blends of ancestral qualities; more frequently they are aggregates, veins of resemblance to one or other of them showing now here and now there. The life-histories of our relatives are, therefore, more instructive to us than those of strangers; they are especially able to forewarn and to encourage us, for they are prophetic of our own futures. If there is such a thing as a natural birthright, I can conceive of none greater than the right of each child to be informed, at first by proxy through his guardians, and afterwards personally, of the life-history, medical and other, of his ancestry. The child is brought into the world without his having any voice at

<sup>1</sup> I think Charles Darwin realised this fully in 1873, and indicates it in the opening sentences of his *Expression of the Emotions*; for him “Expression” itself means kinetic facial changes. “Many works have been written on Expression, but a greater number on Physiognomy,—that is, on the recognition of character through the study of the permanent form of the features. With this latter subject I am not here concerned.” (p. 1.)

<sup>2</sup> There might still be a chance for the film. It would need a super-Galton to organise the technique of a composite film!

<sup>3</sup> This is alas! not the fact. Galton had a large collection of prints and negatives of individuals and of composites. A very large proportion of the prints are now so faded as to be useless; of many the subject is indistinguishable. When I turned to the negatives to replace the prints, I found many negatives had perished also, gone as yellow and faded as the prints, and others were in process of decay. Unless immediate steps be taken to reproduce it in a permanent way, Galton's unpublished photographic work will have practically perished entirely within 50 years of its preparation. Failing some form of ink reproduction—and then it must not be on paper laden with china clay—there is no real security for permanency in photographic negatives and prints. The patchy preservation of Galton's negatives—some faded, some excellent—shows that there is no security that negatives will survive fifty years, the source may lie in varied technique, or in varied quality of chemicals used.

all in the matter, and the smallest amend that those who introduced him there can make, is to furnish him with the most serviceable of all information to him, the complete life-histories of all his near progenitors." (p. 31.)

The idea of portraiture as expressing mental character and that of individuality as measured by deviation from type fascinated Galton throughout the whole of his long life, and he returned to these subjects with great energy even in his last years. He sought to measure the degree of resemblance or of difference in portraits. The amount of labour he put into this research was immense; there is a great mass of manuscript matter, there are endless profiles drawn by his assistants, there are models of apparatus and there is apparatus itself. Without a more definite key than we possess it is often very difficult to trace what line of thought he was following up, although not infrequently one lights on most suggestive ideas in side tracks from the main problem.

That the work in this direction arose from the composite photograph investigations is clear from a lecture Galton gave on May 25, 1888 at the Royal Institution, entitled "Personal Identification and Description<sup>1</sup>". It opens with the following words:

"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 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 particularise. At last I tried to relieve myself as far as might be from this embarrassment, and took considerable trouble, and made some 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." (*Nature*, Vol. xxxviii, p. 173.)

Galton then states that while recognising different degrees of likeness and unlikeness we have not so far as he knows made any attempt to measure them. He now proposes to take for his unit of measurement the *least-discernible difference*.

"The measurement of resemblance by units of least-discernible difference is applicable to shades, colours, sounds, tastes, and to sense-indications generally."

Galton illustrates his method on sight differences; he takes two superposed oval contours (see Fig. *a*, Diagram iv, p. 304), intersecting one another, and then halves the distance between their boundaries for a new contour, and then halves again until he reaches—in his case in the fourth stage—a contour indistinguishable from one of the original contours. He then says there are 16 grades of least-discernible difference between *A* and *B*. The method is suggestive, but obviously liable to difficulties, for it is clear that its measurement is largely *subjective*. It depends on the fineness of drawing of the original contours and of the subdividing contours. It depends also on the scale upon which they are drawn. It is modified by the subjective conditions of the observer, whether his sight is good, and whether he uses or does not

<sup>1</sup> *Nature*, Vol. xxxviii, pp. 173-77, 201-2, 1888; *Proc. Royal Institution*, Vol. xii, pp. 346-60, 1889; my references are to the pages of *Nature*.

use glasses. Also it is clear that the least-discernible difference may be reached at some points long before it is reached at others, or the measure of resemblance would vary from part to part, and ultimately be a measure

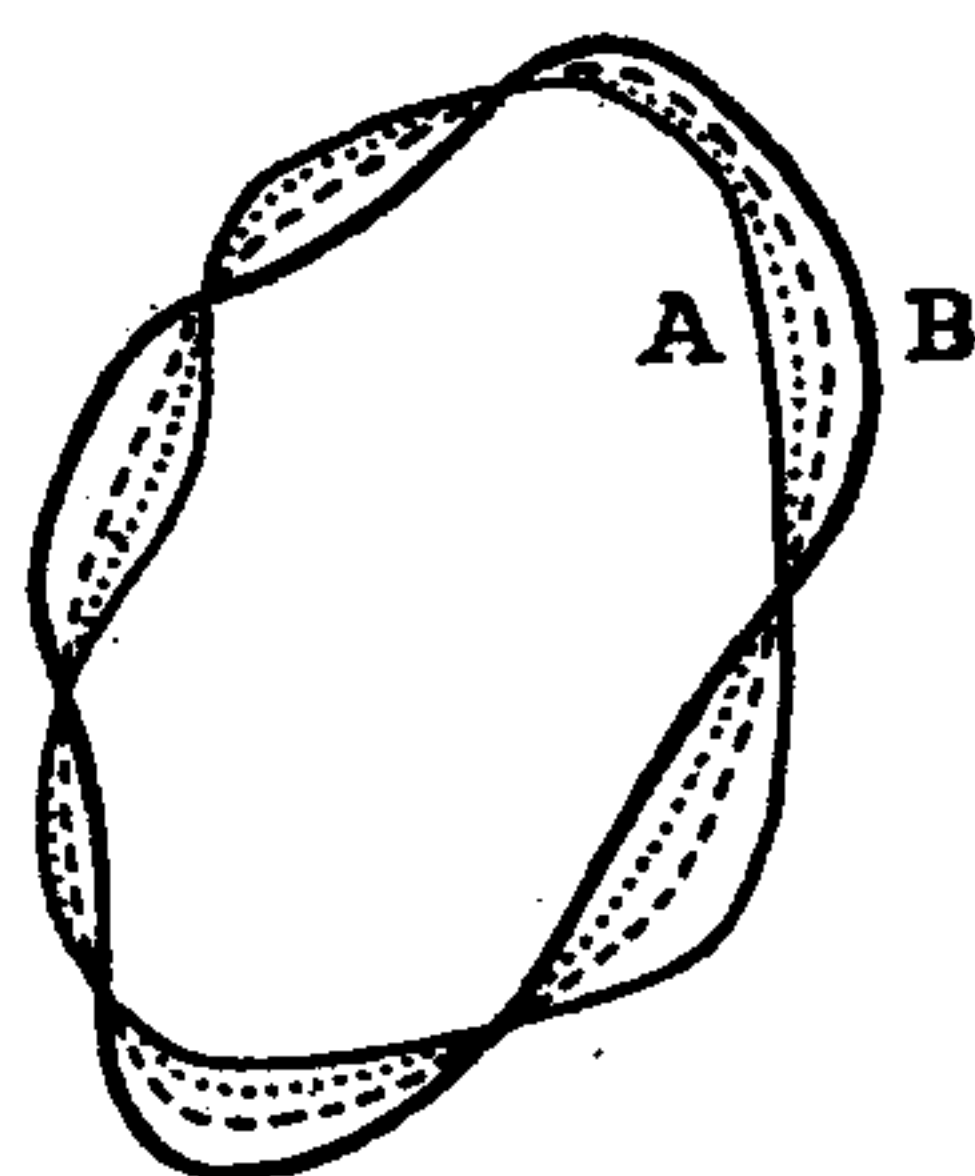


Fig. a.



Fig. b.



Fig. c.

Diagram iv.

of only the most unlike parts. If we agree to an average fineness of line, and an average keenness of sight, we shall still be left with the question of scale<sup>1</sup>.

Dealing with the silhouette, Galton remarks that:

“All human profiles of this kind, when they have been reduced to a uniform vertical 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 they all fall within the space shown in Fig. b. [Galton is working with the distance from the notch that separates the brow from the nose (nasion) to the parting of the lips as standard length.] The outer and inner limits of the space are of course not the profiles of any real faces, but the limits to many profiles, some of which are exceptional at one point and others at another. We can classify the great majority of profiles so that each of them shall be included between the double borders of one, two, or some small number of standard portraits, such as Fig. c. I am as yet unprepared to say how near together the double borders of such standard portraits should be drawn; 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 building up a well-selected standard collection, is a laborious undertaking if attempted in 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.” (p. 174.)

The reader will now be able to perceive better what Galton was really attempting to do by this special illustration: he was aiming at identifying individuals by their profiles, and in order to do this it was needful to index profiles. This leads Galton to the topics of indexing and of entering indices. He first refers to Bertillon's system of identifying criminals, and states that the actual method by which it is done is not all that theoretically could be desired. He notes a fundamental difficulty that arises:

“The fault of all hard-and-fast lines of classification when variability is continuous, is the doubt where to place and where to look for values that are near the limits between two adjacent classes.” (p. 175.)

<sup>1</sup> For example, suppose it be required to find the degree of resemblance between two maps, *A* and *B*, of the same district on different scales; shall we reduce *A* to *B*, or *B* to *A*, for that will clearly affect our judgment? Or, shall we look at them both placed on the table before us, or both hung at some little distance on a wall?

Bertillon divides each of his four fundamental characters into three groups—large, medium, small—and Galton points out that the difference between the men at the extremes of the medium group is, for stature, say 2·3 inches while the possible error of determining stature may be  $\pm 0\cdot5$  inch; that is to say, that there is a total doubtful range of 2 inches, while the medium range itself is only 2·3 inches. He further points out that nearly all Bertillon's characters, we may anticipate, will be highly correlated together and accordingly his 81 ( $=3^4$ ) groups will contain very unequal numbers.

"No attempt has yet been made to estimate the degree of their interdependence. I am therefore having the above measurements (with slight necessary variations) recorded at my anthropometric laboratory for the purpose of doing so." (p. 175.)

I do not think these measurements were ever taken in adequate numbers or that Galton ever determined actually their correlations. This was, I believe, first done by the late Dr Macdonell, on actual criminal data, and he pointed out how, by the use of proper "independent variates," the trouble of correlation in the characters could be eliminated<sup>1</sup>.

The first difficulty, however, of the border-line cases, which involve such a large proportion of the population and therefore the multiplication of cards in several groups, Galton got over by what he termed a "mechanical selector." I have not found any 'selector' described before 1888, but many since, all involving Galton's principle, some patented, without any recognition of Galton's priority. The idea is indeed a very simple one; each individual has a card 8 to 9 inches long. If there are 4 or 6 indexing characters each is allotted something less than a quarter to a sixth of the card. This portion of the card represents the range of the corresponding variate and a notch is cut into the card at the value of the variate within this range<sup>2</sup>. The breadth of this notch represents twice the possible error of measurement, once in excess and once in defect, for that variate. The cards are placed vertically and loosely in a box divided into batches by partitions so that there is not sufficient friction to interfere with their independent motion. The bottom of the box, except sufficient at the ends for the cards to rest on, is replaced by a "keyboard" as Galton termed it; this keyboard is of the breadth of the variate portion of the cards, and can be elevated by a lever. Adjustable wires can be arranged across a gap in the keyboard of the size of the series of cards, and these wires are adjusted to give the measurements of an individual to be selected, just as the notches are cut in the cards. When the keyboard is elevated its wires pass into the notches of those cards which are within possible errors of the individual set on the keyboard—all the other cards but these are raised and thus discriminated from those which require examination. It is clear that the cards do not require classification by size of organs, but may be placed by age or alphabetically. Galton considered that this mechanical

<sup>1</sup> *Biometrika*, Vol. I, pp. 177-227. The Bertillon system of indexing by physical measurements has now been replaced by direct indexing of finger-prints.

<sup>2</sup> Actually the notch would not be cut at the exact value of the variate except when near the boundary of the sub-range; in other positions it would suffice to cut it at the middle of the sub-range. For Bertillon's index it would suffice practically to have pin points marked for each variate on the card, where notches should be cut.

selector of which he gives ample drawings could deal with 500 cards at a time. Of his 'selector' Galton writes:

"Its object is to find which set, out of a standard collection of many sets of measures, resembles any one given set within any degree 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 specific value. The apparatus is very simple; it applies to sets of measures of every description, and ought to act on a large scale as well as it does on a small one, with great rapidity, and be able to test 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 of a large number of successive sets, 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."

Galton then returns to the measurements of the profile and indicates those he would propose to take. These measurements he then suggests should be used with a "mechanical selector." He considers that measurements on the profile would be nearly as trustworthy as those on the limbs for approximate identifications, and he states that their values are less highly correlated than those on the limbs<sup>1</sup>.

This paper shows that Galton at this time had not fully made up his mind as to the best characters by which to measure or index individuality. He considered that personal characteristics existed in much more minute particulars than in the profile:

"The markings of the iris of the eye are of the above kind. They have never been adequately studied except by the makers of artificial eyes, who recognise thousands of varieties of them. These markings well deserve being photographed from life on an enlarged scale."

Besides the handwriting, Galton refers to the bifurcations and interlacements of the superficial veins, and the shape and convolutions of the external ear, and then turns for the first time, I believe, in published work to the small furrows and intervening ridges on the palmar surfaces of hands and feet. To this matter I shall return when dealing with Galton's work on finger-prints. In the concluding paragraph of his lecture Galton tells us that he was induced to make these researches into individuality and personal identification in order to discover independent features which might be suitable for inquiries into heredity.

"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." (p. 202.)

<sup>1</sup> It seems unnecessary to specify Galton's profile measurements here, for opinions will differ as to the suitability of his axes and choice of points. In the Galton Laboratory, by means of special apparatus we mark the auricular point and 'Frankfurt horizontal plane' on the silhouette. The nasion to the auricular point is then taken as a fundamental axis and as the standard length. We have obtained on this basis mean silhouettes for men and women. I should be inclined to measure certain deviations of the individual profile from the mean profile, when the nasio-auricular lines of both coincide in direction and magnitude, as the indexing characters.



While finger-prints are now an accepted form of evidence in our courts of law—only a few newly-appointed and yet uninstructed magistrates questioning their validity—it is singular that no use has hitherto been made of them in cases of doubtful paternity, only vague impressions as to family likeness being given in evidence or apparently thought of importance.

Another lecture closely allied to that just discussed was the Royal Institution Friday evening discourse on January 27, 1893. It is entitled "The Just-Perceptible Difference"<sup>1</sup>. In this lecture Galton starts with a definition:

"We seem to ourselves to belong to two worlds, which are governed by entirely different laws; the world of feeling and the world of matter—the psychical and the physical—whose mutual relations are the subject of the science of Psycho-physics, in which the just-perceptible difference plays a large part.

It will be explained in the first of the two principal divisions of this lecture that the study of just-perceptible differences leads us not only up to, but beyond, the frontier of the mysterious region of mental operations which are not vivid enough to rise above the threshold of consciousness. It will there be shown how important a part is commonly played by the imagination in producing faint sensations, and how its power on those occasions admits of actual measurement." (p. 13.)

Galton started by referring to Weber's Law and illustrating its action by an ingenious mechanical model. He placed on an axle a wheel, a logarithmic or equiangular spiral (perpendicular to the axis and with its pole at the centre of the axle) and an index-hand marking on a scale the angle turned through by the axle. All these were accurately balanced, so that they could rest in any position of the axle; round the wheel was taken a cord carrying a scale-pan at one end and a counterbalance weight to the pan at the other. Round the spiral was taken a second cord fixed at one end to the axle and carrying a ball at the other. If now a weight be put into the scale-pan, the axle will rotate until the increasing ray of the spiral provides leverage enough to balance the weight in the scale-pan. The weight in the scale-pan measuring the 'stimulus,' the angle turned through by the index-hand measures the sensation<sup>2</sup>. Galton demonstrated on the model that as the stimulus grew large the increases of sensation were very small.

"The progressive increase in the effective length of the logarithmic arm is small at first, but is seen soon to augment rapidly, and then to become extravagant. We thus gain a vivid insight through this piece of mechanism into the enormous increase of stimulus, when it is already large, that is required to produce a fresh increment of sensation, and how soon the time must arrive when the organ of sense, like the machine, will break down under the strain rather than admit of being goaded farther.

The result of all this is, that although the senses may perceive very small stimuli, and can endure very large ones without suffering damage, the number of units in the scale of sensation is comparatively small. The hugest increase of good fortune will not make a man who was already well off many degrees happier than before; the utmost torture that can be applied to him will not give much greater pain than he has already suffered. The experience of a life that

<sup>1</sup> *Proc. Royal Institution*, Vol. xiv, pp. 13-26; *Nature*, Vol. XLVII, pp. 319-21, 342-45.

<sup>2</sup> If  $b$  be the effective radius of the wheel,  $w$  the weight in scale-pan,  $W$  the weight of the ball,  $\phi$  the angle of the spiral,  $\theta$  the angle of the scale and  $a$  the linear constant of the spiral, so that its equation is  $r = a e^{\theta \tan \phi}$ , then the principle of moments gives us  $w \times b = W \times r \sin \phi$ , whence  $\theta = \cot \phi \log \frac{r}{a} = \cot \phi \log \frac{b \times w}{a W \sin \phi}$ , which is Weber's Law if  $\theta$  be read as sensation and  $w$  as stimulus. It is easy to modify the mechanism to take account of the 'threshold.'

we call uneventful usually includes a large share of the utmost possible range of human pleasures and human pains. Thus the physiological law which is expressed by Weber's formula is a great leveller, by preventing the diversities of fortune from creating by any means so great a diversity in human happiness." (pp. 14-15.)

Galton notes how the threshold of sensation differs in different persons and how delicacy of perception is a criterion of a superior nature. It may be modified in the same person by health and disease, by drugs and hypnotism.

He notes, however, that external causes of stimulation may be reinforced by internal causes, and that external stimuli which would fail to exceed the threshold may by aid of the imagination be magnified to the production of a just-perceptible sensation. As illustration of this Galton quoted a personal experience which certainly deserves record in a biography for it indicates how Galton worked "habitually searching for the causes and meaning of everything that occurred to him<sup>1</sup>." After citing Wordsworth and Tennyson as cases in which the force of imagination could master their sense of the present real, Galton notes that his own deafness prevented him when seated in the middle rows at a scientific meeting from following memoirs read in tones suitable to the audience at large. He could, however, distinguish the words of the speaker if he had the unrevised proof of the memoir before his eyes. If the speaker used words not in the proof, he failed to catch them, and if he raised his eyes from the proof nothing whatever of the reading could be understood, the overtones by which words are distinguished being too faint to be understood. He found that he had to approach the speaker by one quarter of his distance from him to follow him without the aid of seeing the words. The loudness of the overtones at the two distances would be as 9 to 16, and Galton concluded that his auditory imagination is to that of a just perceptible sound as 16 minus 9 or 7 is to 16.

"So the effect of the imagination in this case reaches nearly half-way to the level of consciousness. If it were a little more than twice as strong it would be able by itself to produce an effect indistinguishable from a real sound." (p. 19.)

He suggests that experiments as to this might be easily made with two copies of the same newspaper, a few words being altered here and there in the copy to be read from.

People growing deaf, although they cannot lip-read, appear to interpret sounds better when they watch the lips of the speaker. Spectators at the theatre, e.g. at the French plays, *hear* better if they follow with a "Book of Words."

Whatever may be thought of Galton's explanation—the internal stimulus due to the imagination—we must recognise that he discovered a most interesting psychological problem in an experience which the bulk of men would never have thought of analysing<sup>2</sup>.

The next part of Galton's paper deals with optical continuity and the just-perceptible distance between two dots. The ordinary eye is just able or just unable to see two dots about a minute of angle asunder. Taking

<sup>1</sup> Charles Darwin: see our p. 1.

<sup>2</sup> A somewhat similar experience occurs in deciphering very bad handwriting; we find it impossible to read the words, until we take to imagining what the writer is likely to be talking about, and with this assistance the eye can often realise what the hieroglyphics stand for.

ordinary reading distance as 12 inches, a row of five dots each  $\frac{1}{300}$ th of an inch in diameter arranged on the page of a book would be like an almost invisible fine and continuous line. A row of 300 dots to the inch will look at a foot like a continuous line, but far fewer dots are interpreted by the imagination as a line. The ordinary cyclostyle works by dotting and has about 140 dots to the inch; the usual half-tone engraving is produced also by dots, but without a lens the illustration appears continuous in its tones and shading. Galton found that with only 50 dots to the inch he could reproduce a profile which many persons to whom it was shown failed to discriminate from an ordinary woodcut. 250 to 350 points gave exceedingly well the profile of a Greek girl copied from a gem<sup>1</sup>.

Taking his points at equal distances Galton found that the direction from one point to the next could be in most cases adequately given by the points of the compass, the top of the paper being treated as north. He takes the letter *a* to represent north, *b* for north-north-east, *c* for north-east and so on in order up to *p*. This presumed, it is possible to represent any profile by a formula. Letters beyond *a* to *p* give points of reference or mark by a sort of bracket points not to be drawn in as when we pass from brow to eye. For convenience Galton breaks up his directional letters into words of five letters each. Thus the profile of the Greek girl involved about 400 letters or 80 words, and might have been sent by telegram. In 1893 it would have cost about £8 to cable it across the Atlantic. Galton illustrated by examples the accuracy with which such portraits, maps or plans could be reproduced. In a postscript added to the printed lecture he gives a coordinate system which allows of somewhat greater exactness, but it requires two numbers to each direction; at the same time it allows variety in the length of the steps.

The whole paper is very characteristic of its author; it leads us from psychological theory to a practical end, the sending of portraits by telegraph; but beneath the whole we find Galton really working at the idea of inherited resemblance as measured by the degree of likeness in the formulae for the profiles of relatives.

We have noted in our first volume that the Galton family was portrayed in a considerable number of very characteristic silhouettes. When Francis Galton turned to the problems of quantitatively measuring resemblance and of indexing portraits, he was compelled by the nature of his subject to deal chiefly with profiles, and from this standpoint he recognised the great value of the silhouette. No doubt thinking of his own family portraits, he addressed two letters to the editor of *The Photographic News*<sup>2</sup>. Silhouettes, he tells the readers of that journal,

“were very familiar to those who lived in the pre-photographic period. They were quickly cut out of paper by a deft hand with a small keen pair of scissors, and at least one of the many operators in this way ranked as an artist capable of making excellent likenesses<sup>3</sup>. The paper

<sup>1</sup> This profile, about 12 inches high, was in the *Galtoniana*, and probably still is, but could not be found recently for reproduction here.

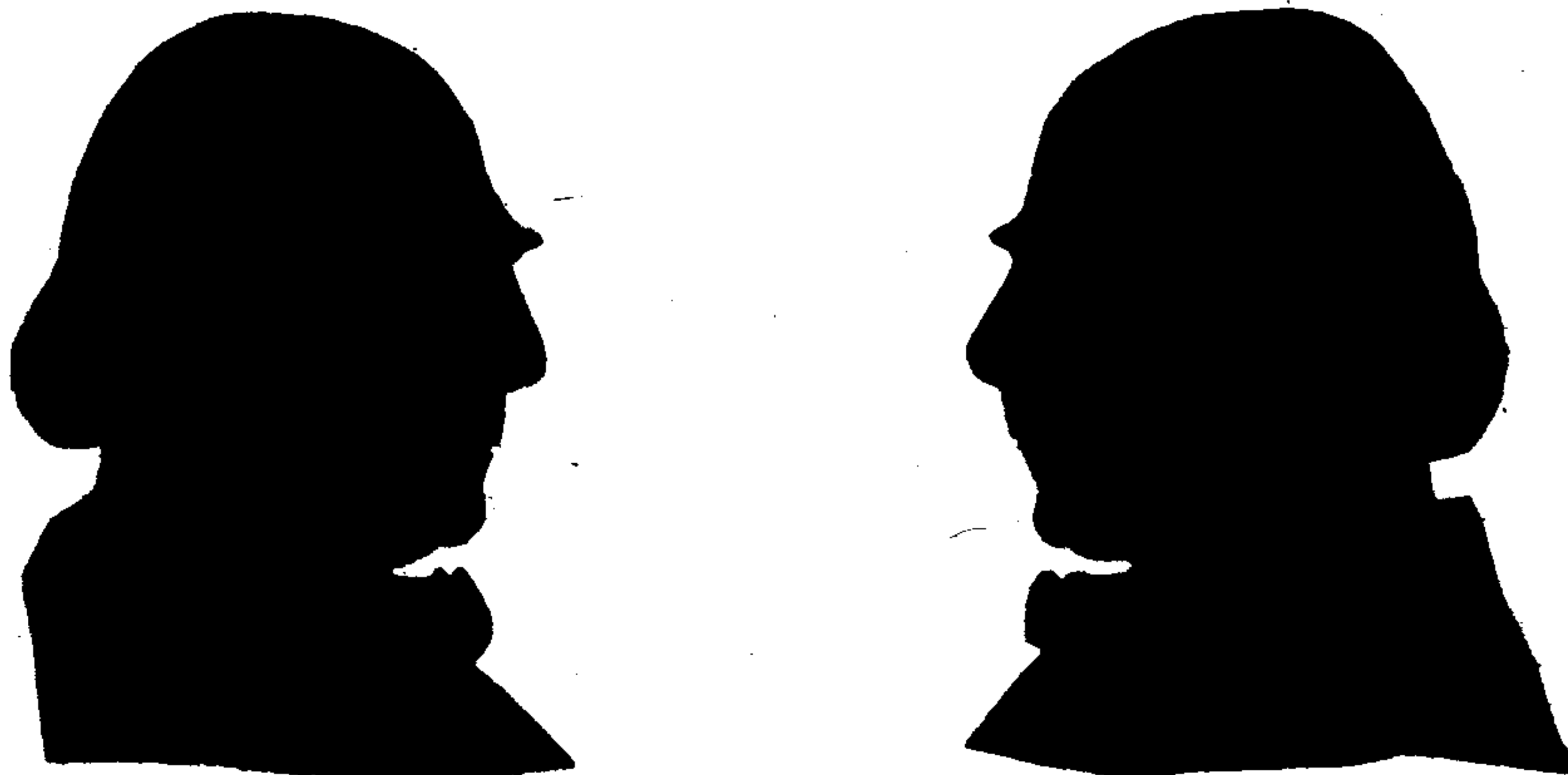
<sup>2</sup> July 15th and July 22nd, 1887.

<sup>3</sup> No doubt Edouard, who did the Galton and Darwin families. See our Vol. 1, Plates IV, XVII, and XXXIV.

was black on one side, and the silhouette that had been cut out was pasted then and there, with the black side upwards, upon a white card, and framed. A perfectly durable and often a good likeness was thereby produced in a very short time. This art was superseded by photography, and is now temporarily extinct; but I want to show that it might with great facility—and I think with some profit in a humble way—be advantageously re-introduced by the help of the very agency that extinguished it.”

Galton next suggests photographing the profile of a sitter, either in a strong light against a dark background, or *vice versa*, and then taking a print of this result, cutting out the profile and blackening it<sup>1</sup>. In his second letter Galton gives an example of a silhouette prepared in this way. Such silhouettes are, he says,

“particularly useful in studying family characteristics which, I think, are on the average far better observed in profiles than in any other single view of the features. The truth of this statement may be verified in church, where whole families, each occupying a pew, can often be seen sideways, and each family can be taken in and its members compared at a single glance.



Galton's photographic silhouettes of himself, aged 65.

The instances will be found numerous in which the profiles of a family are curiously similar, especially those of the mother and her daughters. This is most noticeable where their ages and bodily shapes differ greatly, as when the daughters are partly children and partly slim girls, and the mother is not slim at all.”

It must be admitted that Galton went to church rather for scientific than religious purposes; but the reader of this passage will hardly be inclined to accept Dr Beddoes' statement that Galton was wanting in a sense of humour! See Vol. I, p. 59.

Another photographic problem which occupied a good deal of Galton's thoughts at one time was the problem of keeping the object and the focal plane at the conjugate foci of the optical centre of the object-glass. This

<sup>1</sup> If the sitter be placed in front of a window, a half plate will give a silhouette of about four inches high, which is often a very characteristic portrait. The chief need is the 'deft hand' in cutting out the print and avoiding angles. In the Galton Laboratory we have a silhouetting arrangement in which the sitter's head is adjusted to the 'Frankfurt horizontal plane,' and the shadow is cast by an arc light some fifty yards away. The shadow is traced by an artist's hand and the resulting silhouette preserved with the anthropometric records of the subject. It is used for measurements and by compounding series of subjects to obtain type profiles.

is a very important point in the case of reduction to an exact size. Galton's papers show a large number of attempts at its solution. He ultimately sought the aid of Mr (now Sir) Horace Darwin, who in 1878 published in *Nature*<sup>1</sup> a satisfactory theoretical solution by aid of a double Peaucellier's cell. Galton found, however, that the cells would have to be of unwieldy size, if these arrangements were used. I am not aware that the problem has even yet been solved practically, although for scientific photography its solution is very important.

(C) *Analytical Photography.*

At the same time that Galton was working out his idea of composite portraiture a new problem occurred to him, that of creating what he termed a "transformer" which would transform the type into any individual component. The transformer would thus be a measure of the difference between individual and type, or indeed between any two individuals. He proposed by this method to analyse the differences between types (or races), between individuals (or between an individual and his family type), or between an individual on different occasions. Galton termed the production and study of transformers *Analytical Photography*. The idea appears first to have occurred to him in 1881; but not till 1900 did he write a letter, which appeared in *Nature*<sup>2</sup>, August 2, on the subject, stating the outlines of the process, and speaking somewhat doubtfully of his own power of carrying it out. In this letter, after describing the theory<sup>3</sup> and something of the technique, he writes:

"I photographed two faces, each in two expressions, the one glum and the other smiling broadly. I could turn the glum face into the smiling one, or *vice versa*, by means of the suitable transformer; but the transformers were ghastly to look at, and did not at all give the impression of a detached smile or of a detached glumness."

Later Galton realised that transformers were hieroglyphics which required a key to their interpretation; the photograph of a "smile" is really the photograph of facial modifications which failing the stable basis of the face we do not recognise as a smile at all. I owe to Mr Egon S. Pearson the photographs on p. 312. *A* is the normal, *B* the smiling subject. *C* and *D* are the transformers. *D* is the "glumness" and *C* the "photograph of a smile." All that can be said of the latter is that it does not closely correspond with John Tenniel's conception of the grin which remained some time after the rest of the Cheshire cat had vanished<sup>4</sup>.

<sup>1</sup> Vol. xviii, p. 383.

<sup>2</sup> Vol. LXII, p. 320.

<sup>3</sup> If *x* be the transformer, Galton lays down two equations

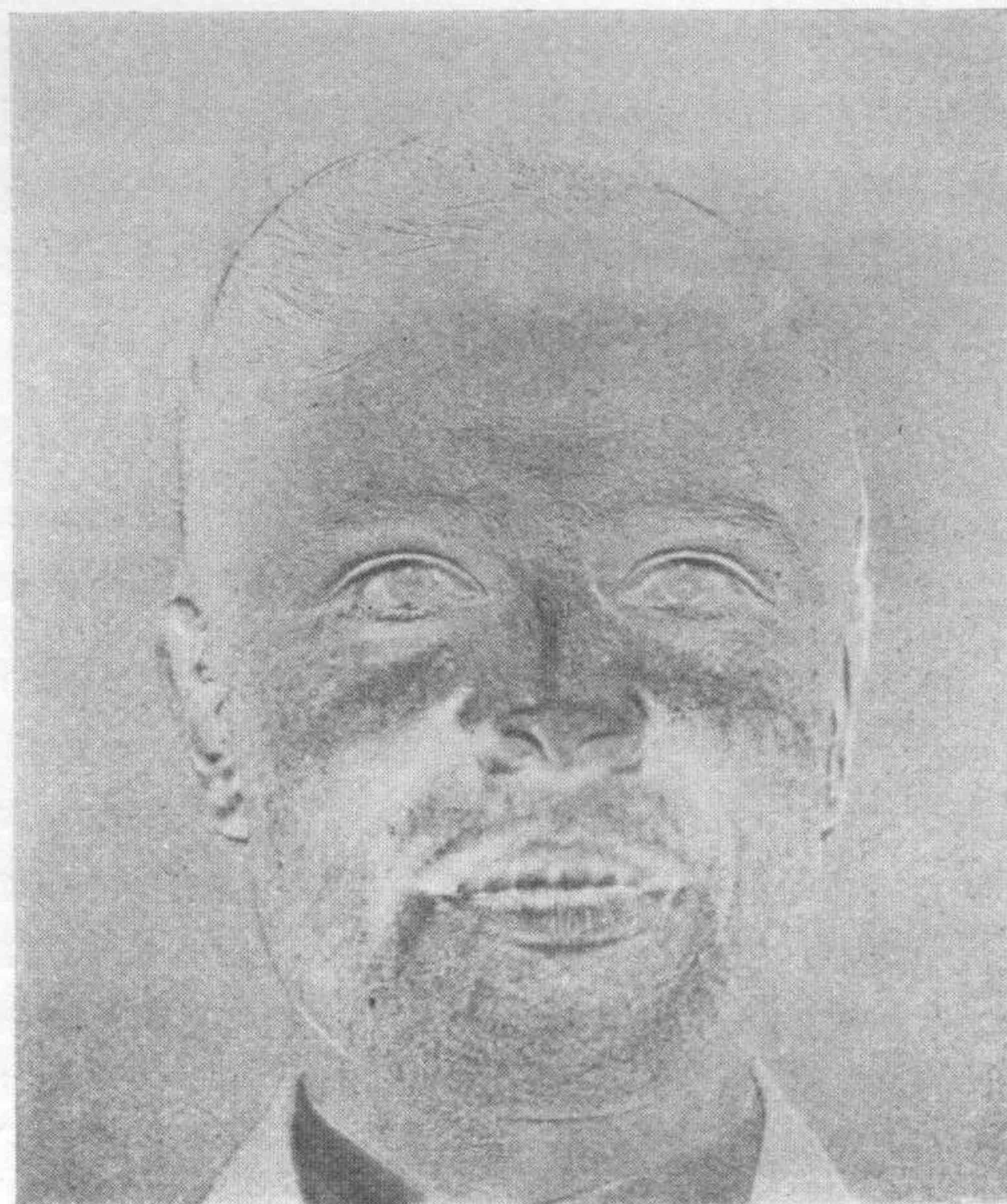
$$(i) \text{ pos. } a + \text{ neg. } a = \text{grey}, \quad \text{and} \quad (ii) \text{ pos. } a + x = \text{pos. } b,$$

whence he deduces

$$(iii) \text{ pos. } a + \{\text{pos. } b + \text{neg. } a\} = \text{pos. } b + \text{grey}, \quad (iv) \text{ pos. } b + \{\text{pos. } a + \text{neg. } b\} = \text{pos. } a + \text{grey}.$$

Thus the quantities in curled brackets are the transformers, one the negative of the other (the "smile" and the "glumness").

<sup>4</sup> *Alice's Adventures in Wonderland*, Edn. 1872, p. 93.

*A**B**C**D*

By November 27, 1900, Galton had devised a simple small apparatus<sup>1</sup>

<sup>1</sup> This is now in the Galton Laboratory. It consists essentially of a triple camera; one object is thrown directly on to the focal plane; the other two by aid of two reflecting prisms are also thrown on to the same plane. The three objects thrown on to the plane are positive *a*, negative *a* and positive *b*. By throwing out one or two of the three we can throw on to the screen (i) positive *a*, (ii) negative *a*, (iii) positive *b*, (iv) positive *a* + negative *a* to show the uniform grey, (v) negative *a* + positive *b*, the transformer, or (vi) positive *a* + the transformer, giving the darkened *b*.

with the aid of Mr T. R. Dallmeyer for carrying out his project, and this was exhibited on the date just mentioned to the Royal Photographic Society; Galton's paper is printed in *The Photographic Journal*, Vol. xxv, pp. 135-38. The idea at the bottom of Analytical Photography is extremely simple, as most of Galton's methods. A subject *A* and a subject *B*, taken in similar positions and of similar size, have faint transparent positives and faint transparent negatives taken of each. If now positive *A* and negative *A* be thrown accurately adjusted on the same screen, they will antagonise each other and give a uniform grey background. If further positive *A* and negative *B* be thrown on the same screen, they will only antagonise one another where the originals are identical; where they are different, they will only in part antagonise each other. Thus the combination of positive *A* and negative *B* gives a representation of their difference on a grey ground. This Galton calls the "transformer." If the transformer be thrown on the screen with positive *B*, it converts positive *B* into positive *A*. Similarly negative *A* and positive *B* is the transformer, which superposed on positive *A*, converts it into *B*. The two transformers are in fact positive and negative of the same difference. In both cases the transformed portrait is that of a darkened subject. The fact that our combination of faint positive and faint negative gives a uniform grey or half tone is very important; because it follows that where our transformer adds nothing in the way of difference to *A* to make *B*, it will still add everywhere this grey or half tone. The transformed *B* will therefore be a *darkened* picture of *A*.

Galton illustrated this point by obtaining a 'real' scale of tints. He took nine teetotums: the first had a white surface, the second a sector of 45° painted black, the third two sectors of 45° black, the fourth three sectors and

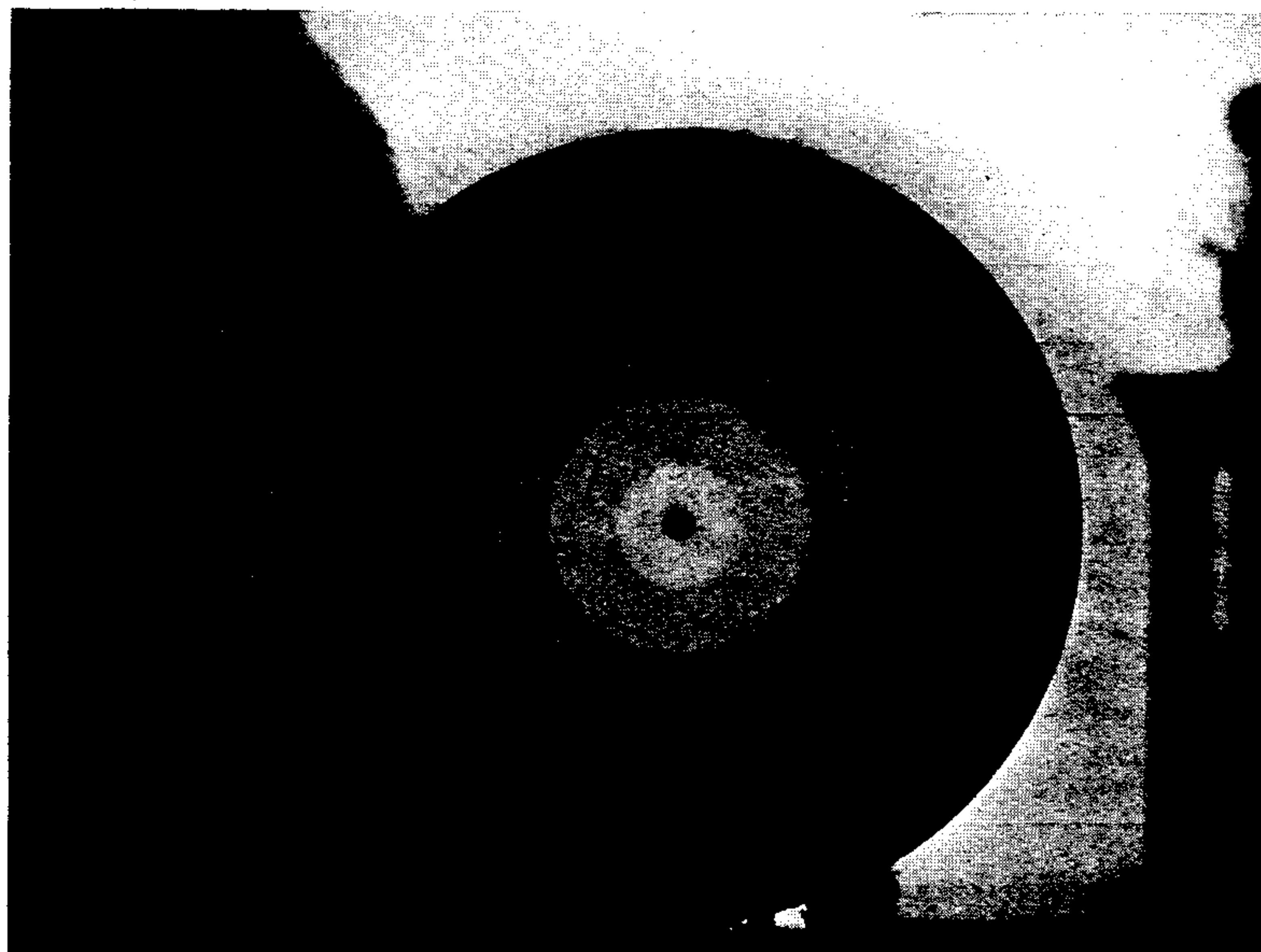


Diagram v. Galton's photograph of a spinning wheel of tints.

so on up to the ninth which was all black. On spinning these nine teetotums, he obtained a 'real' scale of tones from white to black<sup>1</sup>. Having thus obtained a scale of nine tones from white to black, Galton terms the fifth of these (180° painted black) the medium tone. Pictures painted with tones less than, but up to and including, the medium tone he calls 'faint'; pictures painted in tones from the medium to the black, he calls 'dark'. He then caused three portraits of a lady to be painted with these tones:

(a) is the normal painting, using all the tones from 0 to 8, i.e. white to black;

(b) is the faint painting, using all the tones from 0 to 4, i.e. white to medium grey;

(c) is the dark painting, using all the tones from 4 to 8, i.e. medium grey to black.

On Plate XLV will be seen Galton's scale and the portraits. Of these he writes:

"I exhibit three sketches of the same portrait to show the differences of effect under these conditions, and how very little the mere question of more or less likeness is affected by them. All the tones from 0 to 8 were used in painting the first picture. Then a grey mixture that matched the medium grey was made in one corner of a palette and pure white squeezed out in another. The artist by using mixtures of this grey and white, and nothing else, made the second picture as a copy of the first. It is evident that its resemblance is not affected by the limitation of the range of tones. The third picture was made on the same principle as the second, except that black and medium grey were employed instead of white and medium grey, and here again the resemblance to the original is perfect. It follows that the value of the analytical process is not much affected by the fact that it is unable to transform, in other words that it cannot produce a transformer, or in still other words that it cannot isolate the differences between *any* two portraits, but only those between a light half-toned copy of the one and a dark half-toned copy of the other. It should be remarked that although the light-toned *a* and the dark-toned *b* severally contain one-half of the complete scale of tones, yet the transformer of the light-toned *a* into the dark-toned *b* contains the complete scale." (pp. 136-7).

Galton illustrates the whole process well by showing the steps taken to convert any mosaic of four tones into another mosaic of four different tones. He takes tones 6, 4, 2, 2 for *A* and 4, 6, 2, 6 for *B*: see our scale Plate.

(1)	<i>A</i> (Original full-toned portrait)	...	...	6	4	2	2
(2)	<i>B</i> " " "	...	...	4	6	2	6
(3)	<i>pos. a</i> (faint half-tone), i.e. ( $\frac{1}{2}A$ )	...	...	3	2	1	1
(4)	<i>neg. a</i> (faint half-tone), i.e. ( $4 - \frac{1}{2}A$ )	...	...	1	2	3	3
(5)	<i>pos. b</i> (faint half-tone)	...	...	2	3	1	3
(6)	darkened <i>pos. b</i> (i.e. <i>pos. b</i> + 4)	...	...	6	7	5	7
(7)	<i>pos. a</i> + <i>neg. a</i> (uniform grey)	...	...	4	4	4	4
(8)	<i>neg. a</i> + <i>pos. b</i> (the "transformer")	...	...	3	5	4	6
(9)	<i>pos. a</i> + ( <i>neg. a</i> + <i>pos. b</i> ), i.e. (3) + (8) (which is the same as the darkened <i>b</i> , or (6))	...	...	6	7	5	7

The greatest difficulty in the above process is to ensure that positive *b*

<sup>1</sup> Galton carefully distinguishes between the scales of 'real' tones perceived or sense tones and actinic tones. (p. 137.)



4-8 DARK HALF TONES



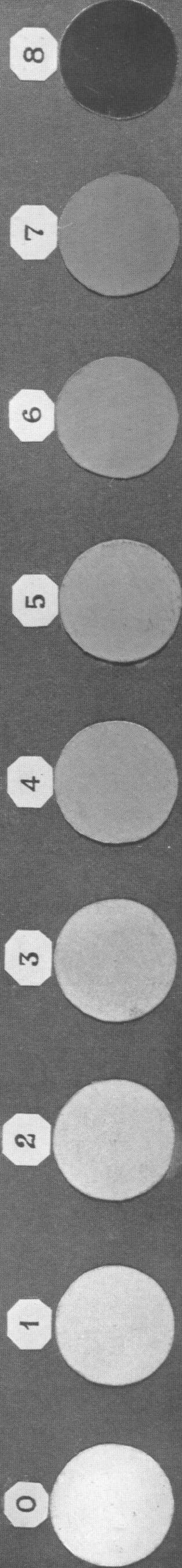
WHOLE SCALE



0-4 LIGHT HALF TONES



SCALE OF TONES



Analytical Photography.  
Oil paintings of a portrait in various tones.

and negative *a* have the same tone, so that if *b* were *a*, the composite would give merely medium grey. It is needful also that *pos. a* and *neg. a* should accurately antagonise one another. Our figure shows one of the illustrations Galton gave at the lecture, namely the "transformer" which will change an **F** into a **G**.

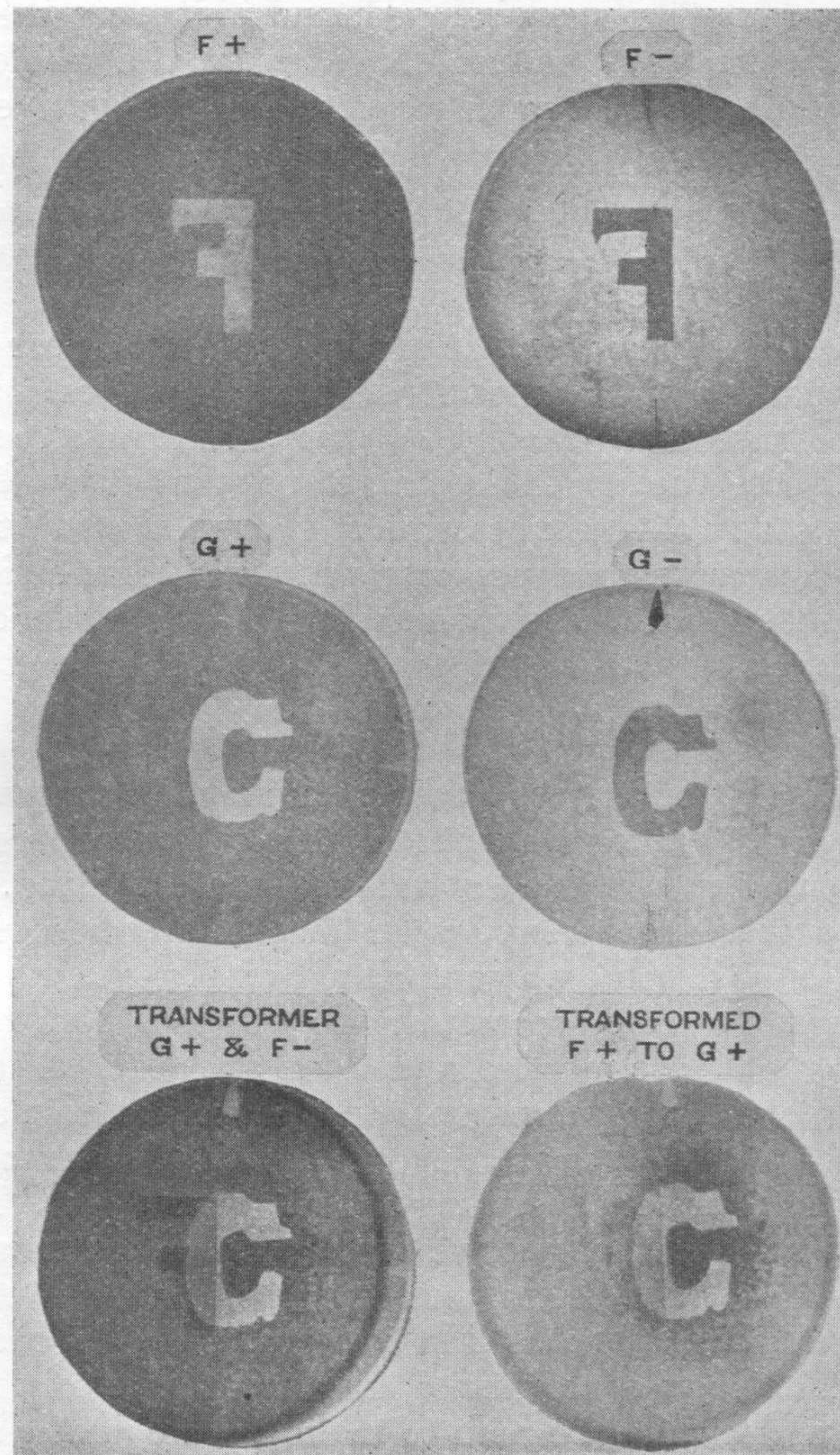


Diagram vi.

Galton also transformed a mosaic St George's Cross into a St Andrew's Cross (slides in *Galtoniana*). It may be said of these results that they were only partially successful—this is the view taken by Sir George Darwin in his account of Galton in the *Dictionary of National Biography* (*Second Suppl.* Vol. II, p. 72). But Galton recognised the main difficulty himself:

“But negatives and positives do not wholly obliterate one another. They do so to all intents and purposes when the tones are not very far from the middle of the scale; an extreme white is not obliterated by its negative.” (p. 137.)

Galton was 78 years of age when the paper was published, and it was hurriedly written (p. 138). He never worked out the technique with the care and elaboration he devoted to composite portraiture. Yet it seems to me that the method is capable of being developed, and if it were the results reached by it would be of very great value. The key to the whole position is the production of a perfectly obliterating positive and negative pair. Galton's original suggestion that

“the only satisfactory experiments now would be those made by two converging lanterns on a screen, one at least of which admits of easy and delicate adjustment in direction and intensity of its illumination”<sup>1</sup>

might still be of aid in the matter. It is possible that the use of homogeneous light in the preparation of both positives and negatives might be of some value. Anyhow I personally should be sorry to dismiss analytical photography as idle. From the psychological standpoint it ought to be of first class value in the study of the expression of the emotions. It should indicate what physical or muscular changes accompany such expression. The subject needs to-day an enthusiastic cultivator, who has the patience to develop its technique.

#### (D) *Measurements by Photography.*

In 1896 Francis Galton started another inquiry. He appears first to have developed a scheme for taking from the same spot two photographs, one with the camera horizontal and the other with the camera tilted. By aid of two such photographs distances were to be measured photographically. The method of reduction is in some way associated with photographs (positive and negative) of a horizontal ruled square divided up into  $20 \times 20$  small squares. The two chief diagonals are marked and there are posts on the square at the centre and the corners. It was apparently capable of rotation about the centre and there are photographs of it with the optical axis of the camera in one of the diagonal planes, and in a plane bisecting the diagonal planes. There are photographs of streets, roofs and chimneys seen from a high parapet, possibly of a bridge, apparently to be used in testing the method. But the manner in which the reticulation was to be used in these cases is very obscure, and so far I have only found the box of negatives, and no explanatory notes or papers, in the *Galtoniana*. It would be rash to make any dogmatic assertion, but it would appear as if Galton at a fairly early date had been independently working at photographic triangulation.

*Photographic Measurement of Distances and Lengths.* No less than eleven notebooks in the *Galtoniana* deal with this topic. They appear to have been started in 1894–1895. They contain not only experimental measurements, but a succession of drafts of papers, changing sometimes by

<sup>1</sup> *Nature*, Vol. LXII, p. 320. Attempts in this direction would have been made before this in the Galton Laboratory, but for inadequacy of funds.

very little the method of procedure, or changing sometimes its applications. There are a good many negatives or prints also referring to the matter, some intelligible, some needing an interpretation, which I have been unable to supply. To one series of such, clearly involving distant objects, I have already drawn attention (see p. 316); a good deal of the matter refers to fairly near objects, and the first experiments—to judge by the photographs—seem to have been made on a series of shelves or racks at the Kew Observatory. Then Galton photographed a bronze horse (Carousel) and determined the three coordinates of eight to eleven points of it in a variety of ways. It is really wonderful thirty years later to see the amount of labour he put into work of this kind. A reader of *Nature* might conclude that his communications to it were brilliant suggestions written in a few hours. This, I believe, was never the case; he rarely refers to a tithe of his experimental work, the calculations, trials and failures he had made before preparing his paper; in many cases a paper was written over and over again before it assumed its final form, and if a reader of the latter thinks the result could have been more easily reached by another method, it is extremely probable that that method could be found, experimentally tested and silently rejected, in one or other of Galton's preliminary notebook records. If he tried and condemned a method, he scarcely ever stated that he had done so. He assumed that his readers would suppose him to have surveyed the country before plotting the selected path to his goal.

Galton started with the general problem of studying the perspective of a photograph; he did this by the simple method of photographing with his subject some horizontal reticulation, or if needful both a horizontal and a vertical reticulation, and this served as the basis for analysing the perspective properties of the photograph. Galton shows that photographic measurements of objects may be divided into two classes; those in which we measure lengths parallel to the focal plane of the camera, and those in which we measure other lines, and in this case we may require two photographs of the same object taken simultaneously from different aspects. The mathematics of the latter are by no means complicated, and are provided by Galton, but his dominant passion for the study of heredity soon led him to the measurement of animals, and by proper orientation of the animal the principal measurements Galton was seeking can be obtained from a single standardised photograph, provided it is accompanied by suitable reticulations or fiducial lines.

In one of his many notebooks I find the draft of a paper which starts thus:

“Architectural draughtsmen are familiar with the art of translating objects into their perspective representations, but the converse process of translating perspectives into their objective equivalents has never, I believe, been yet brought into practice<sup>1</sup>. So long as pictures had to be

<sup>1</sup> It was not an uncommon problem before even 1890 to ask engineering students to draw a model in perspective and then take the measurements of parts of the original model from the perspective drawing. It must be confessed, however, that it was done with the view of testing drawing accuracy and possibly suggesting the superiority of plan and elevation drawings. It would certainly have been good experience to have obtained measurements of the parts of machines by double photographs of them accompanied by suitable reticulations.

drawn by hand and therefore inexactly, there was no inducement to consider the possibilities of this converse process, for which exactitude in the picture is essential to success, but now that photography has become common the old difficulty has disappeared, and the possibilities of the neglected process well deserve consideration. The applications would be numerous and especially valuable in determining and measuring restless animals in their momentary attitudes, or even when in rapid motion, which could not otherwise be measured without difficulty, or when in rapid motion be otherwise measured at all. The object I have especially in view is to establish a system of measuring a large number of domestic animals of various pedigree stocks, whether horses, cattle, sheep, dogs, poultry etc., in order to provide material to advance our knowledge of heredity of a kind that is greatly needed. It is not qualitative facts and exceptional instances that are now wanted by students of heredity, but a large collection of quantitative facts in the form of trustworthy measurements. They are needed to determine with far greater precision than they are at present known the statistical laws and coefficients of heredity. Among these are the conditions and rate of 'regression' of the offspring of exceptional parents; the gradual or sudden alterations of position of the point towards which regression tends, as the breed becomes more pure; the relative influence of the male and female parent in respect to various measurable peculiarities; the intensities of prepotencies; the frequencies and magnitudes of sudden sports, and the degrees of their subsequent stability through successive generations....I should add that the direct measurement of creatures so sensitive, timid and sudden in their actions as thoroughbred horses, who at the same time are often vicious, is difficult and dangerous; similarly as regards bulls and some of the breeds of dogs. Photography is a simpler, more exact and far safer method of measurement in these cases than the direct application of rod, tape and callipers."

We shall consider later Galton's method of determining lengths parallel to or nearly parallel to the focal plane of the camera. This he has published (see our p. 320). His two-camera method of determining the three coordinates in space of any point of a subject has not, as far as I know, been published and deserves a paragraph here.

Diagram vii, figs. 1-5, is taken from Galton's manuscript. Fig. 3 represents the plan on a working scale;  $M_1$ ,  $M_2$  are the plans of the optical centres of the two camera lenses;  $ba$ ,  $cd$  are fiducial lines drawn on the base plane upon which the object stands;  $b$ ,  $a$  and  $c$ ,  $d$  are fiducial points,  $M_1a$  and  $M_2c$  being the traces of the vertical planes through the optical axes of the two cameras, and these are so arranged that  $M_1a$  and  $M_2c$  are accurately at right angles to  $ba$  and  $cd$ . Figs. 1 and 2 represent the two photographs, and  $p_1$  and  $p_2$  the point  $P$  in them whose coordinates are to be determined. From  $p_1$ ,  $p_2$  perpendiculars  $p_1g$  and  $p_2f$  are dropped on the images of the fiducial lines  $ba$  and  $cd$  in the photographs. But clearly  $ag/ba = ag/ba$  and  $fc/cd = fc/cd$ . Hence  $g$  and  $f$  on the plan drawing can be scaled. Produce  $M_1g$  and  $M_2f$  to meet in  $Q$ , then  $Q$  is the plan of the given point  $P$ . If  $S$  be the perpendicular from  $Q$  on  $M_1a$ , we may take  $SQ$  and  $aS$  for our coordinates  $x$  and  $y$ . Now draw to the same scale an elevation (fig. 4) of the system on the vertical plane through the optical axis;  $N_1M_1$  is the height of the optical centre,  $ST$  is the elevation of  $P$ . Since  $Sa$  is known, by joining  $S$  to  $N_1$  we obtain  $s$ . If the elevation of  $P$ , or  $z$ , be  $TS$ , we require to determine  $ts$ , for knowing it we have  $TS/ts = M_1S/M_1a$ . But  $ta$  is  $p_1g$  the apparent height in the first photograph altered in the ratio of  $ab$  to  $ab$ . Fig. 5 illustrates this clearly. Of course we must settle the scale for the drawing-board  $ab$  by the value of the fiduciary distance  $ab$  in the reticulation on the base plane of the object photographed. Such is Galton's very simple process of taking measurements on photographs

of an object. It can indeed be achieved if the object be inanimate by placing it on a reticulated turntable and rotating this turntable through  $45^\circ$  or  $90^\circ$  to obtain the second photograph with the same camera. Of course if we can find the coordinates of one point we can find those of any number, and the

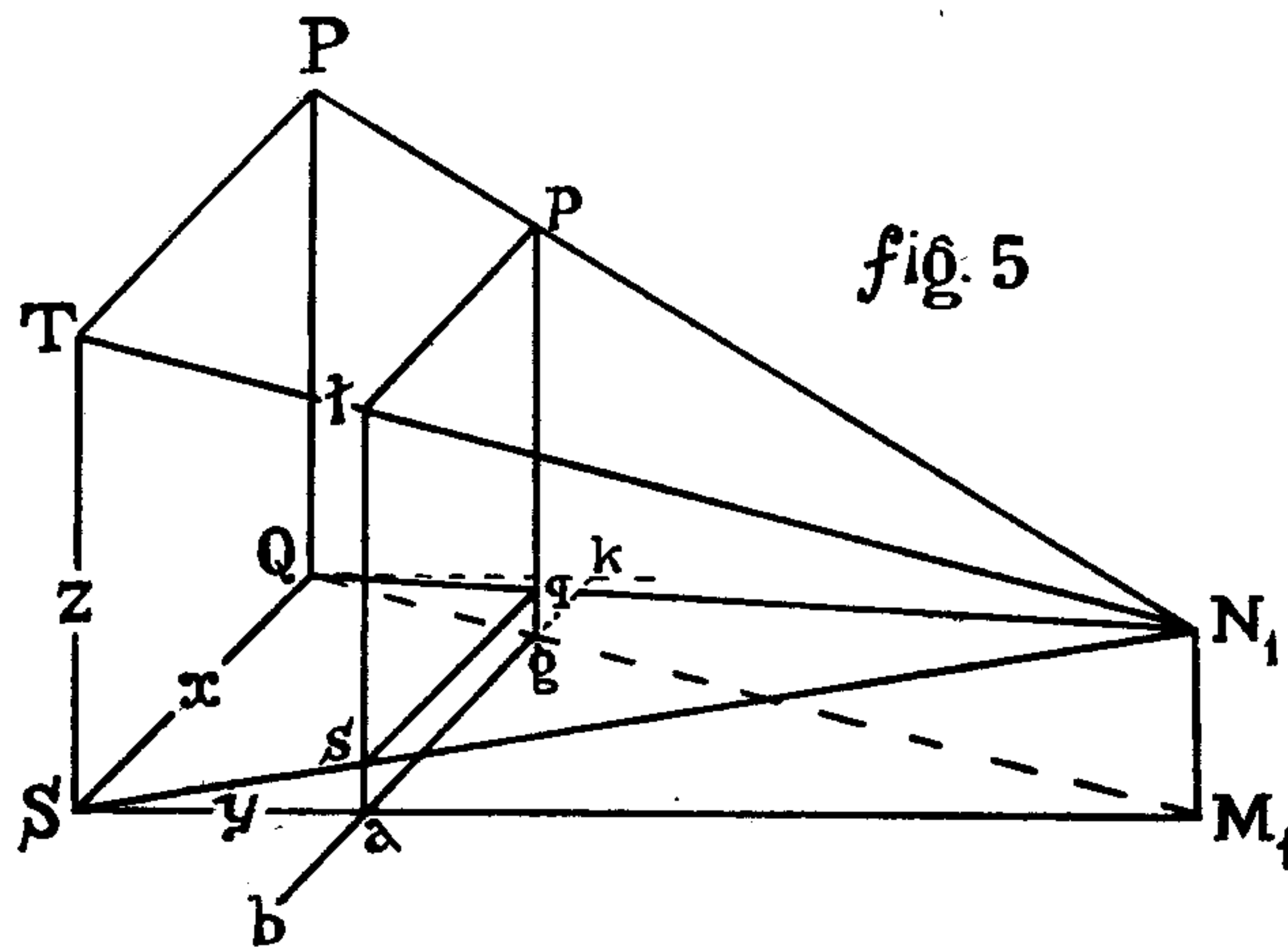
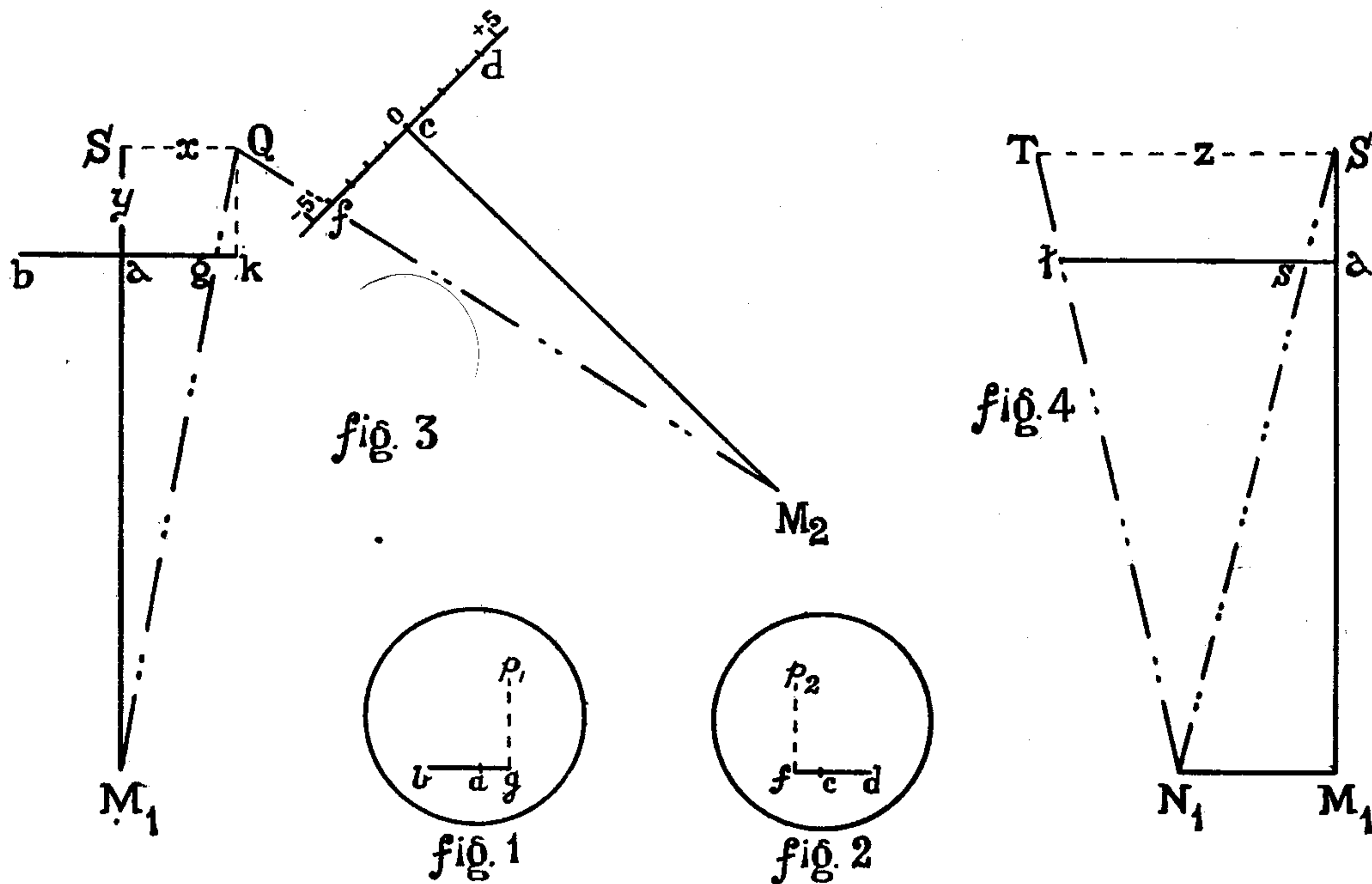


Diagram vii.

distances between them can then be found in the usual way. Another method is to find a whole series of points T and S or construct plan and elevation drawings of the object from the two photographs.

A paper by Galton entitled "Photographic measurement of Horses and

other animals" was published in *Nature* on January 6, 1898<sup>1</sup>. It belongs perhaps more closely to our chapters on biometry and heredity, but I have included it here as concerned chiefly with photographic technique. Galton points out how frequently valuable horses and other show animals are photographed, but owing to the fact that there is no standardised method of arranging animal and camera, it is not possible to take any measurements on these photographs. The standardisation is a fairly easy matter, a rectangle 100 inches long and 20 inches broad is marked on the ground, by preference in front of or parallel to a wall, upon which are two nails in the same horizontal line at some distance apart; a string terminating in two weights is hung over these nails, and the vertical portions should be vertical on the focal plane. A horse, say, is led on to the rectangle so that its feet all lie within it, and so that the tips of its four hoofs and the short ends of the rectangle are all visible in the focal plane. The optical centre of the camera is 5 feet above the ground and 20 feet from the near side of the rectangle measured on the ground; the optical axis is in a plane perpendicular to the long sides of the rectangle and this plane meets the rectangle in a line about 1 foot from its central line and is parallel to the short sides. The camera is tilted somewhat downwards, so that the rectangle and the horse's hoofs shall be visible in the photograph. The focal plane which must be adjustable is made vertical by examining the vertical portions of the string which should be vertical on the focal plane.

If now the mid-point  $S$  on the line joining the tips of the fore-hoofs on the photograph be joined to the mid-point  $T$  on the line joining the tips of the hind-hoofs, this line  $ST$  provides the trace of the median plane of the horse on the ground. Suppose first  $ST$  to be sensibly parallel to the long sides of the base rectangle and to meet the short sides in  $S'$  and  $T'$ , then if  $S'T'$  be measured and equal  $s'$ , it follows that all measurements on the photograph in the median plane must be multiplied by  $100/s'$  to obtain actual measurements on the horse. The photograph of course only shows the section on the median plane of a pencil of rays from the optic centre tangential to the surface of the horse; but Galton calculates that in the case of a horse with the camera 20 feet away, this would not introduce an error of  $\frac{1}{8}$ th of an inch into the measurements. The point would be more serious in the case of some fat stock with backs flat like tables, and in this case a stud 2 inches in height might be fixed in the median plane at any point of the back and the measurement on the photograph taken to its top; afterwards 2 inches would be deducted from the deduced measurement.

If  $ST$  be not parallel to the long sides of the base rectangle, then its slope to those sides can be found by producing it to meet them and dividing its length in inches between them by 20; the secant of the angle corresponding to this slope is the factor by which horizontal lines in the median plane must be multiplied in order to obtain their true value. Galton also indicates how lines not parallel to the median plane can be obtained as from shoulder to haunch bone (p. 232), but a discussion would carry us into too great detail.

<sup>1</sup> Vol. LVII, pp. 230-32.

At the British Association in 1898 Galton applied for and obtained the appointment of a committee consisting of Professor E. B. Poulton, Professor W. F. R. Weldon and himself "to promote the systematic collection of Photographic and other Records of Pedigree Stock." This Committee made a Report to the Association meeting at Dover in 1899 and it was published in the *B. A. Report* for that year (pp. 424-29). The report emphasises the fact that while it is possible in the various Stud-books and Herd-books to trace the ancestry of pedigree stock, these works

"afford scant means for obtaining that distinct presentment of each of the nearer ancestry which is needed for an exact study of the Art of Breeding." (p. 424.)

Information is almost entirely confined to colour, or in the case of horses to height at the withers. While photographs exist it is very difficult indeed to obtain those of sire, dam and produce as adult—what Galton terms a genealogical *triad*—and groups including the grandparents, even in the case of pure-bred shorthorn cattle, are practically unattainable<sup>1</sup>. The reason Galton finds is not far to seek:

"Heredity is a comparatively new science and few people are as yet acquainted with the character of the records most suitable for its study, or are sufficiently impressed with the need for their exactness and persistence. The most important of these records which it seems feasible to obtain are photographs, not merely pretty and well worked-up productions satisfactory to an artistic eye, but rather such as are analogous to the portraits made of criminals, for storage at the central police office, to serve as future means of identification. The desired photographs need to be taken under such conditions as shall ensure their being comparable under equal terms and shall admit of the accurate translation of measurements made upon them into corresponding measurements made on the animals themselves." (p. 424.)

The report then describes the *Standard Conditions*. These are modified considerably from those given in the *Nature* paper. There is to be a solid wall or screen painted blue, a solid pathway in front of it of 6 feet width of light-coloured bricks to show the horse's hoofs up in the photograph. Two lines are drawn on the pathway, one two feet from the wall, and the other two feet from the first; the edge of the path towards the camera is to show in the photograph as a sharp line. On the wall are to be small marks or studs each about the size of a sixpence, arranged in three vertical and three horizontal lines each at an exact distance of 3 feet apart, the bottom row being at a foot above the path level; the camera is to be 30 feet from the wall, and its optical centre at a height of 5 feet.

"The equivalent focus of the lens should not be less than 9 inches, otherwise the photograph will be too small for convenient measurement; the lens used in the experiment [at the Royal Agricultural Hall in March 1899] was of 13 inches focus, with plates of  $6\frac{1}{2} \times 4\frac{3}{4}$  inches, and proved exactly suitable." (p. 426.)

The verticality of the focal plane and its parallelism to the wall are ascertained by the squareness of the stud-network of the wall on the focal plane screen. The camera once adjusted is to remain undisturbed during a whole series of operations. Prominent points on the horse or on cattle may be marked by

<sup>1</sup> What Galton wrote in 1899 remains equally true a quarter of a century later.



white wafers attached by paste<sup>1</sup>. Many detailed suggestions for taking the photographs are given. Galton indicates as in his earlier paper that if all the animal's hoofs fall in the middle two feet of the path, a slight obliquity to the wall will not introduce an error of any importance into the photographic measurements (see our p. 320). Galton's procedure is now somewhat simpler than that which he gave in *Nature*. He projects from the optical centre on to the wall behind the horse, takes the measurement there and reduces in the ratio of distance from that centre to median plane of horse to distance of that centre from the wall. He now considers it adequate instead of determining the median plane by bisecting lines between tips of fore- and hind-hoofs, to take the median plane 6 inches behind the line joining corresponding fore- and hind-hoofs. He gives reasons for believing that the errors of measurements made on the photographs are less than those made by different persons on the same animal.

In the course of the paper he refers to standard photographs made of 28 premium stallions at the Royal Agricultural Hall and to photographs of 31 triads made on pure-bred shorthorn cattle, chiefly at Alnwick Park. The Royal Commission on Horse-Breeding was asked to permit a trial installation at their show at the Royal Agricultural Hall in 1898, and permission was cordially granted. The installation was made and 35 horses were photographed in 3½ hours. The total cost including that of two veterinary measurers was under £25, and Galton believed that if the operations became customary, the cost would be paid by the sales of copies of the standard photographs.

Galton's Report occupies pp. 12-16 (with plate of figures) of the *7th Annual Report of the Royal Commission on Horse-Breeding* (C. 9487, 1899). He gives some strong arguments for standardised photography and describes again in detail the standardised methods, and the divergences between the photographic and veterinary measures. He considers the latter as far more reliable than the former. In the matter of

"length of body, the photographic method is the only one to be depended on, and it seems to be as trustworthy as that of height." (p. 15.)

Putting aside the length<sup>2</sup> we have for the horse "Maroni" for example :

Height in inches.

	At Withers	At Back	At Croup
From Photograph	65.1	60.7	64.6
Veterinary Measurement	65.5	61.0	64.5

as an illustration of the extent of agreement.

<sup>1</sup> Associated with this section of the material in the *Galtoniana* is a careful drawing of a horse by W. F. R. Weldon with anatomical sketches of the skeleton indicating the points which could be approximated to on the living animal, and suggesting suitable measurements.

<sup>2</sup> "A direct and trustworthy measurement of the length of a vicious or timid horse is extremely difficult, perhaps impracticable." (p. 15.)

"The main result of this experiment has been to prove the feasibility of taking photographs of horses at a Show, that shall be acceptable as ordinary portraits, and will at the same time be of sterling scientific value. I beg in consequence to express a hope that the Royal Commissioners may think fit to arrange that photography under standard conditions shall become a permanent feature of their annual Shows, it being impossible to ensure that those conditions shall be strictly attended to when animals are photographed at their homes, though easy to do so at a public exhibition. The experience gained by this trial...proves how inexpensive, and at the same time how necessary it is to have an appropriate installation, one that might be removed and replaced when desired....If the Royal Commissioners led the way, other societies who exhibit at the Royal Agricultural Hall would doubtless be glad to follow their example and to avail themselves of the installation. The managers of local exhibitions would in time pursue a like practice, until the custom of utilising exhibitions for the purpose of photographing prize winners under standard conditions became general, and probably more or less self-supporting, and the principal object of the Committee of the British Association...would be attained. Horses and other pedigree animals are usually exhibited more than once, so occasional failures due to bad weather admit of being subsequently rectified." (p. 13.)

The general idea of standard photographs of pedigree stock was a splendid one; the results of the trials seem to have been quite satisfactory, but I can find no trace after 1899 either of further work by the British Association Committee<sup>1</sup> or of further photography at the Agricultural Hall. Galton was already 77 years of age, and this was only one of many inquiries he had in hand. There was need probably of an active and younger man to push the matter to a complete success. This want was not satisfied, and Galton's suggestion did not at that time bring forth fruit. Possibly after another quarter of a century we shall find it successfully carried out in America or in some continental country with a keener appreciation than our own of the value of scientific breeding.

(E) *Indexing and Numeralisation of Portraits.*

For 13 years after 1893 (see our p. 307), Galton published nothing further about methods of indexing and numeralising portraits, but he worked most energetically at them. He divided the profile into parts—forehead, nose, lips, chin. He had discovered—what is soon forced on the craniologist—that the component bones of the skulls of two individuals may be extremely alike, but that great differences may be produced by change in angle at the sutures or joints. Now Galton's collection of profiles was most extensive; it ran to many hundreds. He obtained them from drawings—he took 68 from Dance alone—from photographs, and from engravings of all sorts, and again directly by silhouettes; he proceeded to break up his profiles into component parts. From hundreds of noses or chins, he constructed a mean nose or chin. Then he proceeded to measure deviations from these mean noses or chins, and constructed standard patterns of noses or chins. A new profile might be described as having Forehead No. 3, Nose No. 31, Lips No. 26 and Chin No. 8. The individuality of the profile was thus determined and a means given for indexing it. All that was needed in order to get something of a likeness was to add the angles between the joints and fix the magnification to be given to each component.

<sup>1</sup> No further report was made and the Committee lapsed in 1901. I do not know the reason why; nor have I been able to discover what became of the material collected by the Committee. Professor Poulton knows nothing about it; it is not in the *Galtoniana*, nor among Weldon's papers.

A profile therefore would be specified by four numbers, each of which might be two figures, four magnifications say each of two figures, and three angles say also given by two figures to nearest degree. In other words 22, say 30, symbols in a telegram would suffice; thus *six* words in code would convey a creditable likeness of a man. Galton even supposed in his later days that wireless could be used to communicate to the captain of a liner the profile of a person suspected to be on board, whom it might be desirable to keep a watch upon.

Drawings of profiles of men of different races, Copts, Arabs, Negroes, etc. were taken as well as men of every grade of distinction in our own country; at least three or four artists were employed at different times in the preparation of these profiles. There are endless notebooks, measurements, materials of all kinds, and drafts of papers, I believe, never completed and published. I can trace no sign of discontent with the methods adopted, but it would appear as if Galton was always seeking for something better. He had collected data for a work which would certainly have eclipsed Lavater's, being based on much more accurate methods; there is material and suggestions enough for a scientific treatise on physiognomy. Let us remember what Galton had in view, for there is more than one strand in his researches:

(i) He wanted to numeralise physiognomies; he dealt chiefly with profiles, but not wholly. For each profile he wanted a formula from which it could be satisfactorily reproduced. Thus an individual could be identified by 80 words of 5 letters or figures each. This enabled a very sufficient likeness to be telephoned, telegraphed or 'wirelessed.'

(ii) He wanted to index portraits, in particular, profiles. This needed a simplification of the individual formula, and in 1907 he reduced his formula for the purpose of indexing to 4 or at most 6 standard points.

(iii) He wanted to obtain a quantitative measure of the degree of resemblance with three special aims:

- (a) for the purpose of measuring hereditary likenesses or differences,
- (b) for the purpose of measuring racial likenesses or differences,
- (c) for the purpose of ascertaining whether special types of physiognomy were correlated with definite mental or moral characters.

He may be said to have solved (i) in a fairly satisfactory manner before his lectures of 1888 and 1893. In 1907 he was satisfied with his method of "lexiconising" or indexing profiles by standard points. In 1906 he was busy with (iii), and he then apparently threw over any idea of measuring resemblance by likeness of formulae<sup>1</sup> and turned to optical methods, at first that of distance and ultimately that of "blurring," to get a measure of "mistakability." I have a set of "blurrers" he presented to me shortly before his death, and the method was at least ingenious, if not reduced to a final scientific statement. Not having completed his solution of (iii), he never lived to apply his methods to the mass of material he had collected for the discussion of (iii) (a), (b), (c).

<sup>1</sup> The problem presents exactly the same difficulties as the discovery of a single coefficient to measure racial differences when 30 or 40 measurements have been made on two series of crania.

To conclude our consideration of this matter we must give some account of the published papers of 1906 and 1907, and of Galton's unpublished ideas as to "blurrers."

I deal first with the paper of 1907<sup>1</sup>. Galton writes:

"It will be shown that it is easy to 'lexiconise' portraits by arranging the measurements between a few pairs of these points [standardised or "cardinal points"] in numerical order, on the same principle that words are lexiconised in dictionaries in alphabetical order, and to define facial peculiarities with greater exactness than might have been expected." (p. 617.)

The cardinal points selected by Galton are (*c*) the tip of the chin (*pogonion*), (*n*) the tip of the nose, (*f*) the hollow between nose and brow (*nasion*), (*m*) the hollow between upper lip and nose, (*l*) tip of lower and (*u*) tip of upper lip. None of these are really points but vaguely limited regions, and Galton proceeds to define them more closely. A tangent to chin and nasal hollow *YY* is drawn, a line *Y'Y'* parallel to this to touch the nose is then drawn, and finally a tangent to nose and chin intersects *YY* and *Y'Y'* in points *C* and *N*, which give the first two cardinal points. A line drawn from *N* tangential to the nasal hollow gives *F* by intersection with *YY*, and tangents

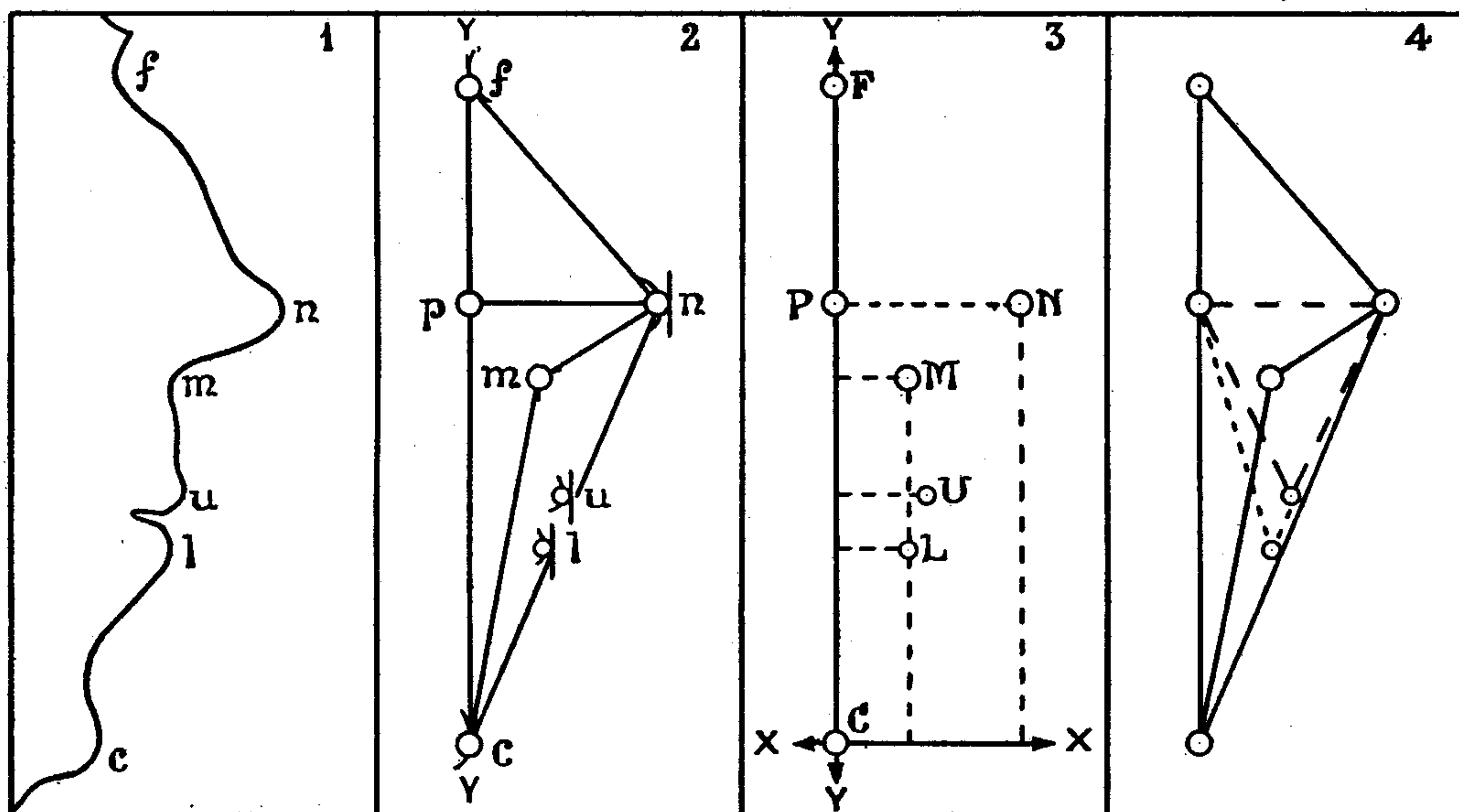


Diagram viii.

to the region *m* from *N* and *C* intersect in the cardinal point *M*. To obtain the upper lip point *U* we draw a tangent parallel to *CF* to touch *u* and a tangent to touch *u* from *N*, their intersection is *U*. Similarly we draw a tangent to *l* parallel to *CF* and to *l* through *C* and their point of intersection is *L*. Galton found that the position of the six cardinal points *F*, *C*, *N*, *M*, *U*, *L*, when reduced to a common scale in which *CF* represented 100 units or "cents<sup>2</sup>," was sufficient to "lexiconise" profiles. The processes might

<sup>1</sup> "Classification of Portraits," *Nature*, Vol. LXXVI, pp. 617-18, October 17, 1907.

<sup>2</sup> A "cent" on the mean profile for a life-sized adult portrait is about 1.25 mm. or  $\frac{1}{20}$  inch.

be by distances between the points or by coordinates taking *YCFY* and its perpendicular *XCX* as axes. Galton preferred on the whole the indexing by coordinates. Working merely with the four coordinates of *M* and *N* read only to the nearest cent, Galton was able to index Dance's 68 profiles so that no two of the numerical formulæ agreed. In two-thirds of the series the smallest difference between the most resembling pairs was 3 cents in one or more measures.

"This conspicuous difference, equivalent to between  $\frac{1}{8}$ th and  $\frac{1}{7}$ th of an inch in a portrait of the natural size, could never be due to the inherent imperfection of the art of measurement, but to some gross blunder." (p. 618.)

Galton thinks that in 1000 profiles indexed on the basis of the coordinates of *N* and *M* *only* there would be some duplicates and perhaps some triplicates. Even these would be reduced by indexing *U* or *L*, or possibly both of them. Galton concludes as follows:

"In the report of a Committee appointed by the Secretary of State in 1894 (C. 7263, price 10*d.*) to inquire into the best means available for identifying habitual criminals, the following remark appears on p. 18: 'An enormous amount of time is spent in examining the books of photographs. It will be seen from the figures furnished by Chief Inspector Neave that on March 1 last twenty-one officers searched for twenty-seven prisoners—the total time spent being  $57\frac{1}{2}$  hours—and made seven identifications. This was an average of more than two hours for each prisoner sought for, and more than eight hours for each identification.' A similar search in a lexicon of portraits of the same size would occupy apparently fewer minutes than the above occupied hours.

I will go no further now into the results of my experiments than to say that I have applied the above method to portraits of persons of very different races, and have thus far found it efficient in all of them." (p. 618.)

In a paper<sup>1</sup> published in the last year, 1910, of his life, Galton returns to his ideas of standard points and of 'jointed' profiles. He simplifies and combines the methods we have already referred to. The simplification reduces his description to four 'words' of five figures. But it may well be doubted whether the simplification is not at too great an expense of accuracy. His title "Numeralised Profiles for Classification and Recognition" shows that he was endeavouring to combine two matters, which are more or less incompatible: (*a*) adequate but brief cataloguing, indexing, or as Galton terms it "lexiconising" of profiles with (*b*) reproduction of a profile from what is scarcely more than an index formula. Actually Galton's work does not apply to the whole profile, but only to the portion from nasion, the nasal bridge to pogonion, the tip of the chin. He takes as his five standard points<sup>2</sup>: the nasion *F*, the nose tip, or say, the rhinion *N*, the notch between the upper lip and the nose, the nasolabial point or hypercheilon *M*, the parting of the lips or syncheilion *S*—no longer the two lip-tips (see our p. 325)—and the tip of the chin or pogonion *C*.

<sup>1</sup> *Nature*, Vol. LXXXIII, pp. 127–30, March 31, 1910.

<sup>2</sup> These points are clearly to be determined by tangents to the profile as described on our p. 325. Although Galton does not here state this, yet his standard types and profiles indicate it. It is doubtful how he defines his syncheilion, marked as a point in his standard types and profiles; probably it was taken to bisect the line joining the theoretical lip-tips of the previous paper. The nasion and pogonion are accepted names in anthropometry; I have ventured to supply names to the other standard points.

Two of these five standard points, nasion *F* and pogonion *C*, are used to get an absolute base. *CF* is taken vertical, treated as axis of *y*, and made 50 units in length, the unit being with Galton a millimetre; no fractions being given. The axis *CX* of *x* is taken perpendicular to *CF*, and the coordinates of *N*, *M* and *S* require two double-figure numbers each for plotting. Thus far we have reached a lexicon in which naso-pogonial length and the coordinates of rhinion, hypercheilon and syncheilon would enable us to identify a profile—the errors of measurement being as Galton says small as compared to the variations due to individuality.

Galton now proceeds to the specification by nine types of each (ten in the case of the nose) of the seven parts of the profile from nasion to pogonion. These are (i) shape of nasion and slope of brow to be superposed at *F*,

	1	2	3	4	5	6	7	8	9	0	
(i)	RAD: 2 BACK 	RAD: 2 VERT'L 	RAD: 2 FOR'DS 	RAD: 6 BACK 	RAD: 6 VERT'L 	RAD: 6 FOR'DS 	RAD: 10 BACK 	RAD: 10 VERT'L 	RAD: 10 FOR'DS 	STR'T 	Dot = <i>F</i>
(ii)	SLIGHT SIN'S 	SLIGHT C.CAVE 	SLIGHT C.VEX 	MEDIUM SIN'S 	MARKED C.CAVE 	MARKED C.VEX 	UPPER 3rd C.VEX 	LOWER 3rd C.VEX 			
(iii)	RAD: 2 STR'T 	RAD: 2 SIN'S 	RAD: 2 C.VEX 	RAD: 6 STR'T 	RAD: 6 SIN'S 	RAD: 6 C.VEX 	RAD: 10 STR'T 	RAD: 10 SIN'S 	RAD: 10 C.VEX 		Dot = <i>N</i>
(iv)	ANGLE STR'T 	ANGLE C.CAVE 	ANGLE C.VEX 	RAD: 2 STR'T 	RAD: 2 C.CAVE 	RAD: 2 C.VEX 	RAD: 6 STR'T 	RAD: 6 C.CAVE 	RAD: 6 C.VEX 		Dot = <i>M</i>
(v)	EVEN SHUT 	EVEN PARTED 	EVEN V. OPEN 	UPPER PR SHUT 	UPPER PR PARTED 	UPPER PR V. OPEN 	UNDER PR SHUT 	UNDER PR PARTED 	UNDER PR V. OPEN 		Dot = <i>S</i>
(vi)	SMALL SMALL 	SMALL MEDIUM 	SMALL LARGE 	MEDIUM SMALL 	MEDIUM MEDIUM 	MEDIUM LARGE 	LARGE SMALL 	LARGE MEDIUM 	LARGE LARGE 		
(vii)	RAD: 2 UPPER 3rd 	RAD: 2 MIDDLE 	RAD: 2 LOWER 3rd 	RAD: 6 UPPER 3rd 	RAD: 6 MIDDLE 	RAD: 6 LOWER 3rd 	RAD: 10 UPPER 3rd 	RAD: 10 MIDDLE 	RAD: 10 LOWER 3rd 		

Diagram ix.

The dots represent the position of standard points.

(ii) nose from nasion to rhinion, (iii) nostril from rhinion to hypercheilon, (iv) upper lip from hypercheilon to lip-parting, (v) nature of the lip-parting with reference to syncheilon as origin, (vi) size of upper and lower lips respectively, (vii) outline of chin between border of lower lip and pogonion.

The type of each portion is here given by a single number. We have

thus twelve figures for coordinates and seven for types and we can communicate this in four 'words' of five figures with one figure to spare. After the standard points have been put in on tracing paper, Galton suggests that tracings should be taken of the seven selected standard forms on to this paper very faintly; next

"to harmonise the whole tentatively with faint and brushlike strokes; lastly, with a free and firm hand to draw the outline through them." (p. 128.)

Now there is little doubt that Galton's original method of numeralising profiles allowed their reproduction with astonishing accuracy, and that his original six standard points permit of their accurate lexiconising. Only experience could determine whether the loss of exactness in this his final four-word method would not be at the cost of a considerable part of the certainty of recognition. Galton in his paper in *Nature* gives eight illustrations and says—with which any one examining the results would agree—that they are by no means deficient in resemblance to their originals.

"I think they are considerably more like to them than the sketches, usually printed in the illustrated newspapers, are to the public characters whom they profess to represent. They are, to say the least, of considerable negative value sufficing to eliminate at the rate of about nineteen out of every twenty individuals as *not* being the person referred to." (p. 129.)

It must be remembered that the resemblance provided is between a profile and a profile, not between the actual person and the four-worded reproduction of his profile. Dance almost in the manner of a caricaturist emphasised individual characters especially the nasal, and this I fancy renders in the illustrations given in *Nature* identification of the accurate profiles, and their rough reproductions, relatively easy; it would be a harder matter with the living subjects of the profiles. Only some experience could test the utility, but it would be worth testing as the police value would undoubtedly be large.

Galton fully recognised the limitations of these rougher methods, and noted that the next step to an accurate profile is a large one<sup>1</sup>, requiring our four-word formula to be replaced by one of fifty or more words. Galton had numeralised many profiles in this more elaborate way and found that normal sighted persons who examined them at a distance of 12 inches in a somewhat careless way did not distinguish them from the originals. By such profiles it would be possible to recognise the living. I am far less certain that the rough profiles suggested in the 1910 paper would be adequate, they certainly would not preserve anything in the nature of an artistic characterisation, which 50 to 80 word formulae undoubtedly achieve. Here we must leave the matter as Galton left it, until another scientific worker feels able to spend a like number of years and an equal enthusiasm on the analysis of portraiture.

<sup>1</sup> "I do not find that a general resemblance can be much increased by using one or a few more quintets or words." (p. 130.)

(F) *Measurements of Resemblance.*

I have already referred to Galton's long-continued researches on the measurement of resemblance. He gave in *Nature*, October 4, 1906<sup>1</sup>, some account of his method and of his apparatus<sup>2</sup> for measuring his "index of mistakability." He opens his account with the following words:

"At the distance of a few scores of paces the human face appears to be a uniform reddish blur, with no separate features. On a nearer approach specks begin to be seen corresponding to the eyes and mouth. These gradually increase in distinctness, until—at about thirty paces—the features become so clear that a hitherto unknown person could thereafter be recognised with some assurance. There is no better opportunity of observing the effects of distance in confounding human faces than by watching soldiers at a review. Their dress is alike, their pose is the same, the light falls upon them from the same direction, and they are often immovable for a considerable time. It is then noticeable how some faces are indistinguishable at distances where great diversity is apparent in others, and the rudely-defined idea will be justified that the distance at which two faces are just mistakable for one another might serve as a trustworthy basis for the measurement of resemblance. The same may be said of obscurity, of confused refractions, and of turbid media."

In the apparatus described in this paper in *Nature*, Galton used distance. But he also looked at two portraits through a graded series of "blurrers<sup>3</sup>," or glasses with different thicknesses of Canada Balsam placed upon them. Finally he adopted a neutral coloured wedge (like the wedge photometer used for star magnitudes), looking at the portraits through thicker and thicker parts of it until they were "mistakable." The apparatus is fairly simple for the distance observations. There is a six-foot base board upon which are two sledges carried along its length by endless cords each going round their own pair of wheels, one at either end of the board. At the summit of the base board, which slopes slightly downwards from the observer, is a screen with an eye-slit to carry spectacle lenses for examining the photographs; it can be replaced by a bracket upon which optical combinations can be mounted for throwing the photographs to a considerable distance, i.e. greater than that of the base board, in the manner of an inverted telescope. The sledges each carry a standard to which the portraits to be examined can be attached, and when attached they can be rotated in azimuth to compensate for differences of degree in the photographs of "half" face. The position of the photographs with regard to the observer's eye can be read on a scale which runs down the centre of the base board.

Galton's procedure is as follows: He first measures in millimetres the distances  $u$  and  $u'$  from the pupil line to the lip line of each portrait. He then takes from the base board scale the distances  $d$  and  $d'$  of the two portraits from the eye screen in centimetres. If now the indices  $n = 100u/d$  and  $n' = 100u'/d'$  be formed, then when they are equal, the two portraits subtend the same angle at the eye, and this allows for any difference in size.

<sup>1</sup> Vol. LXXIV, pp. 562-3.

<sup>2</sup> Now with a good many additions, devised by Galton himself, in the Galton Laboratory.

<sup>3</sup> He presented me in 1907 with a series of "blurrers" and there are a good many sets in the *Galtoniana*, but I have not come across any account of their preparation and standardisation. The photometric wedge is a much more permanent measurer.



If we vary  $n = n'$  taking a whole series of values for them, we reach a value  $N$  at which the two portraits can be mistaken for portraits of the *same* individual. This value of  $N$  is Galton's "index of mistakability." Two persons will have little resemblance to each other, if they must be put at a great distance off to be mistaken for each other; when they are very like each other the distance will be small or the index of mistakability will be large. The index if it can be determined is therefore a measure of general resemblance. "Faces," Galton writes,

"that are alike are certainly [in-]distinguishable at shorter distances than unlike ones, and I notice no excessive clustering of values closely round particular values of  $N$  in my results, which there would be if mistakability always occurred near a particular stage, such as that at which the whites of the eyes cease to be visible, or at twice or three times that distance. A strong likeness in small details may so dominate the perception that a want of likeness in larger features is overlooked. Here the distance of maximum mistakability will be small, the portraits appearing more unlike when removed farther off, and the small details ceasing to be visible. Extreme cases of partial likeness, whether in contour or in detail, would of course be noted and allowed for. With these exceptions the index of mistakability appears to be a fair, even, as I think, a close, approximation to an index of resemblance when the quality of the observed likeness is recorded by appropriate letters as will be described later.

The observational value of mistakability lies in its asking a simple question which different persons would answer in the same way, when they had become familiar with the method." (p. 562.)

The difficulty about the distance measure of mistakability lies in the fact that the comparison of two portraits of different sizes involves continued resetting of the portraits at different distances. To expedite matters Galton tabled  $d$  for given  $u$  and  $n$ , so that the operator knowing  $u$  and  $u'$  could quickly send the two portraits to their proper distances for a given  $n$ . Nevertheless the continual shifting for each new judgment is laborious. Galton then proceeded to prepare test types and noted the  $d$  at which each row of figures was just unreadable. If now a test line be put against the portraits themselves when they are just mistakable in a clear light, we can interchange  $d$  and readability of a certain type. By marking the types by bold values of  $d$  we replace our distance scale by a type scale. Now if the hindrance to vision increases the portraits with the test card must be brought nearer to the eye, and they will increase simultaneously in legibility. The written  $d$  will always show what the true  $d$  would be in a clear light. We now see how the "blurrers," wedge or inverted telescope<sup>1</sup> are to be used; we can keep the actual  $d$  constant, and measure the apparent  $d$  on the card of test types placed alongside the portraits.

Galton's reduction to test types seems to emphasise an obvious criticism—the judgment of the index of mistakability will be dependent on the keenness of vision of the operator. Hence different operators would need differently marked test cards, and there would be a need to correct the index for personal equation, if the results of operators with marked dif-

<sup>1</sup> At one stage of Galton's experiments he made "blurrers" of gauze of different meshes. I think it likely he discarded these because the visibility so largely depends on the position of the network between eye and object. Type absolutely illegible if the gauze be midway between eye and object becomes legible if the gauze screen be quite close to object or to eye.

ferences of keenness of vision had to be pooled. Galton considers that mutual mistakability may occur under any one or more of the following conditions, which he thinks should be noted alongside the index :

- “*aa.* The portraits are apparently exact copies or reductions on different scales.
- a.* They appear to be portraits of the same person at about the same age, though differing in pose and dress.
- b.* They would be mistaken for portraits of the same person, even though they differ in sex and considerably in age, if the hair had been cut and dyed alike, and the dress arranged in the same way.
- c.* As above, if much disguised, as for theatrical impersonations.
- b-c.* Applies to cases intermediate between *b* and *c*.
- p.* Their resemblance is partial only, being confined to specified features.

The applications of the process are numerous, as must always be the case when a hitherto vague perception is brought within the grip of numerical precision. To myself it has the special interest of enabling the departure of individual features from a standard type to be expressed numerically. The departure may be from a composite of their race, or from a particular individual. The shortcomings of a pedigree animal from a highly distinguished ancestor could be measured in this way. Many other examples might be given.” (p. 563.)

As in his profile work Galton used a very large number of pairs of photographs of relatives to test his index of mistakability upon. He asked in the newspapers for photographs of families, and they appear to have been rained down upon him; some material was suitable, some quite unsuitable! It seems to me that to get reliable measures of resemblance special photographs should be taken—full face and profile, the hair being screened under a tight fitting elastic cap. Further if bearded individuals are to be one of the “comparates,” then the comparison must further be made with the chin and lips screened; the eye is very apt to be misled in its judgments by extraneous characters such as hair and pose.

A manuscript typed and prepared for press in February 1906, entitled “The Measurement of Visual Resemblance,” seems never to have been published. It adopts a somewhat different index to that finally chosen by Galton in October of the same year. He begins by saying that visual resemblance between any two objects may be measured in units whose value is strictly defined.

“Resemblance is independent of actual magnitude and has therefore to be expressed in angular units. It is curious that no popular terms exist to express them in the language of any civilised country, for not only would they be useful, but the diameter of the sun when paled by an intervening screen affords an excellent and practically constant standard for rough measurement. It would often be well to indicate objects in a distant landscape by describing them as so many sun-breadths to the right or left of some conspicuous feature, or to speak of a mountain seen from a specified place as towering so many sun-breadths in height, or as bulking so many [square] sun-breadths in area. But as sun-breadths are not terms in popular use, and as they are not the best unit for the purpose of this memoir, I will employ another that is. The sun’s diameter may be taken as subtending an angle of 31·0 minutes of a degree. I will employ for my unit the diameter of an imaginary mock sun that subtends 34·4 minutes, and is therefore wider than that of the real sun in the proportion of 10 to 9. Its merit lies in the fact that the tangent as also the arc of 34·4 minutes differ insensibly from 0·01; in other words the angular unit is that which is subtended by 1 measure of any kind, at the distance of 100 measures of the same kind. I will call the arc subtended by this angle at any specified distance a ‘sol’.”

Galton now gives a paragraph of considerable importance which shows that he had anticipated and met the criticism which naturally arises on reading his second paper.

“The portions of objects to be compared and between which Resemblance is to be measured must be strictly defined. Non-essentials may be either marked out or be simply ignored, but there must be no vagueness as to the limits of the portions selected for comparison. If the objects be portraits the selected portion may be any specified part of the whole of it. It may be a single feature, it may be the face irrespectively of hair, and of beard if any, it may be the whole head, or it may be the entire person. But, whatever it may be, it must be defined.”

After defining the objects for comparison as comparates, Galton continues:

“The compare is limited to the portion under comparison, the two comparates are supposed to be reduced to similar scales, to be mounted side by side on the same moveable screen squarely to the line of sight, and to be viewed in a good light through a perfectly transparent atmosphere.”

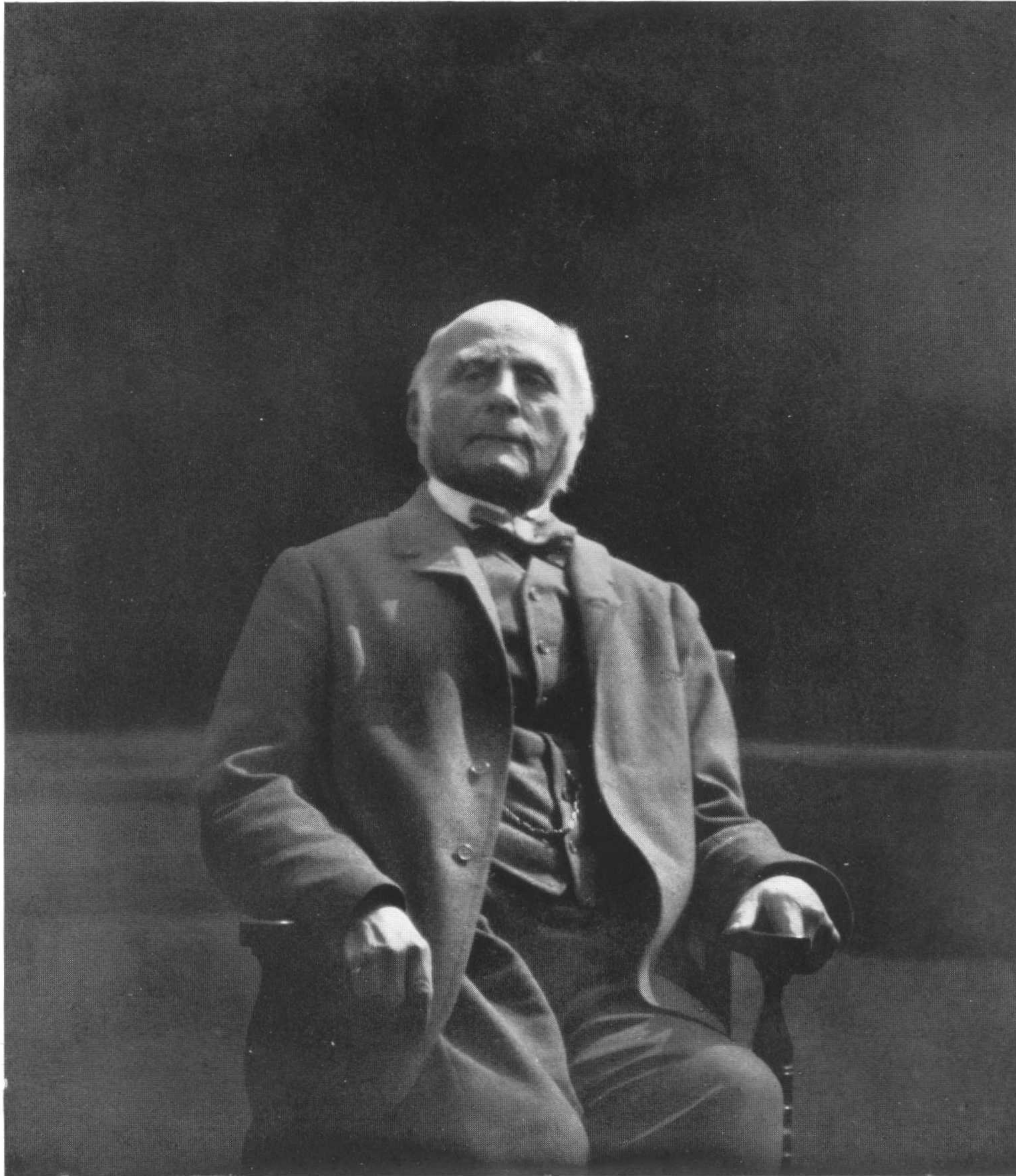
Now in order to conduct the experiments successfully the experimenter requires to have the power of adapting the focus of his eye sharply to the various distances of the screen or to use an optical contrivance to supply this faculty if he should be deficient in it—at the time of writing this paper Galton was 84 years old, and the following words are very characteristic and indicate at least the nature of one of his ‘toys,’ which I had puzzled over:

“The range of adaptability of my own eye, as in that of most elderly persons, has become very narrow, and during a long time was the cause of serious embarrassment in my various experiments on Resemblance. But all this difficulty was happily removed by a small inverting telescope of very low power, that I made abroad in a very makeshift way, out of two small magnifying glasses that I had by me, with pasted paper tubes and corks. It acted so well that I was loath to replace it by a better. Its field of view was ample and enabled me to focus my eye sharply on ‘comparates’ at any distance from a few inches upwards. I will call telescopes that neither magnify nor minify by the name of *Isoscopes*; their use is simply to secure a sharp focus for the eye at any distance. Two convex lenses of 2 inches focal length seem to be on the whole most suitable for an isoscope. The tubes must admit of a wide range of adjustment. Either lens may serve as the eye-piece, but when used as such it should be covered by a cap with an eyehole. Distances must be measured from the object-glass. An isoscope should be fitted with two eye-pieces one of them furnished with a micrometer of crossed lines [i.e. an areal micrometer]. If the eye-piece be of 2 inches focus, and the distances between the lines one 50th of an inch, the intervals between them will subtend 1 sol and each small square will subtend one square-sol.”

Galton proposes to take as his index of mistakability the number of square sols covered by either compare when they are at the ‘critical distance,’ and the corresponding angle is the critical angle. The measure of Resemblance between two comparates, he says, is the angular area of either of them at the critical distance when the comparates as a whole are mutually mistakable. The angular area as a whole is proportional to the number of just-distinguishable plots (i.e. for the normal eye plots of about 1 minute diameter) which they contain, the possibility of mistaking one compare for another being due to apparent identity in every one of the just-distinguishable plots. The more numerous the plots, the more minute is the coincidence, and consequently the closer the resemblance. It will be seen that the entire difference between this earlier and the later paper of Galton is the measurement by a solid instead of a plane angle.



Elizabeth Anne Galton (1808–1906), Mrs Wheler, February 21, 1904, aged 96.  
From the last photograph taken.



Francis Galton, aged 83, from a photograph taken by W. F. R. Weldon in July, 1905.  
“I enclose the best I can do with one of the negatives you were kind enough to let me make. Please forgive my caricaturing you in this way. You know enough about the lower forms of man to know that respect and affection show themselves in strange ways—look upon this as one of them, and pardon it.” W. F. R. W.

Apart from the question, however, of whether the eye does pass under review and ascertain the apparent identity of all these just-distinguishable plots, we may ask what would happen to the relative measurement in the following cases:

*A.* All the plots are absolutely alike except a few which are extremely different, say two identical twins one only with a mole on the face.

*B.* All the plots are different but not widely different.

The comparates in case *B* would present a higher index of mistakability than those in *A*, for we should have in the case of *A* to proceed with distancing the comparates until the isolated anomalous feature disappeared. It might be nothing of course so easily observed and allowed for as a mole, but the measure seems largely to depend upon items of extreme divergence rather than on an average of *all* comparable plots.

Nevertheless the whole investigation is of great suggestiveness, and its originality striking for a man of Galton's then age. He saw a great need, and he did his best to supply it, spending a large part of many years over the problem. If he did not fully solve it, no one has done so much towards its solution, and no one to this day has tested his work, his apparatus or his method and ascertained how far they would carry us.

"The measurement of Resemblance is of wider importance than may appear at first sight. It covers a field of research that escapes the ordinary measurements by foot rule, scales and watch. It is particularly applicable to a variety of biological studies in which hereditary likenesses and family or racial peculiarities are inquired into, and seems eminently suitable for comparing composite photographs. The account of the method I propose has been given merely in outline. It presents many side-issues of interest, and deserves a large amount of photographic illustration such as I am now unable to give."

Thus wrote the veteran of 84! What is needed is that some one should take up the subject where Galton was forced to leave it, starting possibly with his material and apparatus. What are the average degrees of resemblance of parent and child, of brothers and sisters, of first cousins, etc.? And would the results obtained from Galton's Index of Mistakability correspond with those found by the principle of correlation from a single character in kinsmen of various degrees?

The number of years over which Galton's photographic researches are stretched is in itself remarkable, but more remarkable still is the amount of time in those years he devoted to them. I have spent weeks in going through his manuscripts, his published papers, his photographic apparatus, his negatives and his prints, with the view of writing the account in this chapter, but it is more than possible that I have missed points of interest in the overwhelming mass of his material. The suggestiveness of his contributions to portraiture seems to me great, but long as he lived he had only time to blaze the trail. In heredity and statistics a younger generation has been found to take up his work; in photography and portraiture his pioneer steps have not yet been trodden into a well-marked track by enthusiastic disciples.