Faces and Photography in 19th-Century Visual Science

Wade, Nicholas J.

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Faces and photography in 19th century visual science

Nicholas J. Wade
Psychology, University of Dundee, UK

Abstract
Reading faces for identity, character and expression is as old as humanity but representing these states is relatively recent. From the 16th century, physiognomists both classified character in terms of facial form and represented the types graphically. Darwin distinguished between physiognomy (which concerned static features reflecting character) and expression (which was dynamic and reflected emotions). Artists represented personality, pleasure and pain in their paintings and drawings but the scientific study of faces was revolutionised by photography in the 19th century. Rather than relying on artistic abstractions of fleeting facial expressions, scientists photographed what the eye could not discriminate. Photography was applied first to stereoscopic portraiture (by Wheatstone) then to the study of facial expressions (by Duchenne) and to identity (by Galton and Bertillon). Photography opened new methods for investigating face perception, most markedly with Galton's composites derived from combining aligned photographs of many sitters. In the same decade (1870s) Kühne took the process of photography as model for the chemical action of light in the retina. These developments and their developers are described and fixed in time but the ideas they initiated have proved impossible to stop.

Keywords
Faces, photography, stereoscopic vision, apparent motion, face recognition, facial expression, composite faces, optograms, history of visual science

> “What the hand of the artist was unable to accomplish, the chemical action of light, directed by the camera, has enabled us to effect.” (Wheatstone, 1852, p. 7)

Introduction

Faces have fascinated artists and scientists because of the clues they might offer to identity, character and expression. Faces have been carried on coinage since ancient times and they have been painted to convey the spirits of the dead beyond the grave (as with the Fayum mummy portraits). Painted portraits tended to be confined to the wealthy or influential prior to the invention of photography. However, it is not portraiture itself that is of concern here but the influence of photography on experimental studies of vision, particularly in the context of stereoscopic depiction, the demands for accurate identification and the study of facial expressions. The scientists of the 17th and 18th centuries who investigated character and expression as evident in faces had to rely on their own observations or the distillation of the facial states by artists. Those who believed that character could be determined from facial form were called physiognomists although they often speculated on the links between emotions and facial expressions. Darwin (1872) distinguished between physiognomy (which concerned static features reflecting character) and expression (which was dynamic and reflected emotions). Artists continue to apply their skills at representing personality, pleasure and pain in their paintings and drawings but the scientific study of faces was revolutionised by photography in the mid nineteenth century. Rather than relying on artistic abstractions of fleeting facial expressions, scientists were able to enlist photographs that captured what the eye could not discriminate. In a slightly different context, Wheatstone (1852) encapsulated this distinction in the context of stereoscopic portraiture; paired photographs removed the demands of draughtsmanship in producing stereoscopic views of objects, including people. The stereoscope and photographic camera were invented at about the same time and were joined in an early marriage.

Faces could be photographed from two positions so that, when mounted in a stereoscope, they appeared in depth. Expressions could be induced by electrical stimulation of facial muscles or simulated by actors and then photographed. Multiple faces could be aligned on a single photographic plate to produce an average and this was initially applied to defined groups like criminals. Identifying individuals (again initially criminals) was assisted by taking photographs of them full face and in profile. Detecting crime was also implicated in the idea, suggested by scientists, that the image of a murderer’s face was retained in the eye of the victim. Each of these areas will be examined in the context of 19th century advances.

Photography

The birth of photography is generally taken as the year 1839, when first Daguerre (Figure 1, left) made public his positive method, followed quickly by the announcement of a paper-based negative process by Talbot (Figure 1, right). This date was endorsed by Talbot (1844): “I think the year 1839 may fairly be considered as the real date of birth of the Photographic Art, that is to say, its first public disclosure to the world” (p. 12). Daguerre treated silvered-copper metal plates to make them sensitive to light which after exposure produced single positives called daguerreotypes whereas Talbot coated paper with silver chloride so that a negative image was formed following exposure to light; positives could be formed by contact printing the negatives.

Figure 1. Daguerreotypes of (left) Jacques Louis Mandé Daguerre (1787-1851) by Jean-Baptiste Sabatier-Blot and (right) William Henry Fox Talbot (1800-1877) by Antoine Claudet, both taken in 1844.

However, many attempts to capture images in a camera were conducted prior to 1839. Newhall (1982), in his authoritative history of photography, commenced his chapter on the invention of the process with the statement that: "The first person to attempt to record the camera image by means of the action of light was Thomas Wedgwood" (p. 13). Wedgwood (Figure 2, left) had attempted to capture images in a camera with a lens, but without success:

> The images formed by means of a camera obscura, have been found to be too faint to produce, in any moderate time, an effect upon the nitrate of silver. To copy these images was the first object of Mr. Wedgwood, in his researches on this subject, and for this purpose he first used the nitrate of silver, which was mentioned to him by a friend, as a substance very sensible to the influence of light; but all his numerous experiments as to their primary end proved unsuccessful. (Davy, 1802, p. 172)

The article appeared without a named author in the first and only volume of the *Journals of the Royal Institution of Great Britain*, and it is generally attributed to Davy (Figure 2, centre); he was the newly appointed Professor of Chemistry at the Royal Institution and one of the editors of the *Journals*. It is not known when Wedgwood conducted the experiments, but the dates of 1799 and early 1802 are possibilities (Barnes, 2005; Batchen, 1993; Litchfield, 1903). In 1798, Wedgwood had been instrumental in funding and founding the Pneumatic Clinic at Clifton, near Bristol, where Davy conducted research (including the discovery of 'laughing gas') before moving to London. Niépce (Figure 2, right) exhibited his positive and permanent camera images in 1827; he called them heliographs. He had been conducting experiments with camera images since 1816 and had formed negative images on white paper, but like Wedgwood, could not fix them. As a consequence of copying engravings onto metal plates he applied a similar procedure to the camera – forming positive images on metal or glass (see Newhall, 1982). Niépce went into partnership with Daguerre in 1829, but died before Daguerre had devised a way of exposing iodised silver or copper plates in a camera and developing the latent image with mercury vapours.

Figure 2. Left, a negative portrait of Tom Wedgwood (1771-1805) derived from a frontispiece photograph of a chalk drawing in Litchfield (1903). Centre, Humphry Davy (1778-1829), detail after an engraving in *The Gallery of Portraits: with Memoirs*, volume 1 (London: Charles Knight, 1833); in 1802 he described the negative process invented by Wedgwood. Right, Joseph Nicéphore Niépce (1765-1833) who formed the first permanent positive camera images on metal and glass in 1826 (after a frontispiece photograph of a painting in Werge, 1890).

Davy did suggest that muriate (chloride) of silver was more sensitive to light than nitrate, but the main problem faced by Wedgwood was one of fixing the images once the paper or leather had been exposed. They had to be viewed by candle light otherwise the whole surface would blacken. That is, Wedgwood found a way of forming negative images by blocking the light reaching the paper (what would now be called contact printing) but he could not fix the images so formed.

Talbot had been experimenting with images formed in a camera obscura (with a lens) since 1834, and he described his progress in the first photographic book, *The Pencil of Nature* (Talbot, 1844). In it, he expressed his debt to Wedgwood:

> It is curious and interesting, and certainly establishes their claim as the first inventors of the Photographic Art, though the actual progress they made in it was small. They succeeded, indeed, in obtaining impressions from solar light of flat objects laid upon a sheet of prepared paper, but they say they found it impossible to fix or preserve those pictures: all their numerous efforts to do so having failed. And with respect to the principal branch of the Art, viz. the taking pictures of distant objects with a Camera Obscura, they attempted to do so, but obtained no result at all, however long the experiment lasted. While therefore due praise should be awarded to them for making the attempt, they have no claim to the actual discovery of any process by which such a picture can really be obtained. It is remarkable that the failure in this respect appeared so complete, that the subject was soon after abandoned both by themselves and others, and as far as we can find, it was never resumed again. The thing fell into entire oblivion for more than thirty years: and therefore, though the Daguerreotype was not so entirely new a conception as M. Daguerre and the French Institute imagined, and though my own labours had been still more directly anticipated by Wedgwood. (Talbot, 1844, pp. 11-12)

While the image quality of daguerreotypes was initially superior to that derived from printing the paper negatives, chemical coatings with greater sensitivity to light were soon introduced, reducing the exposure times necessary for forming images. The term ‘negative’ when applied to pictorial images was introduced by photography. However, problems associated with recognising negatives of faces was not studied in the 19th century and came to prominence with the renewed interest in face recognition in the 20th century (see Bruce & Young, 1998).

The perceived influence that the invention of photography would have on painting was immediate, even if the predicted demise of painting proved misguided (Vaizey, 1982). In the year Daguerre and Talbot published details of their inventions, the painter, Paul Delaroche, is reported to have declared "From today, painting is dead". The role played by photography in what is now referred to as 'visual culture' has been widely examined (see Bantjes, 2015; Crary, 1990; Ellenbogen, 2012; Silverman, 1993), but the application of photography to experimental investigations of vision has received less attention. Rather than considering the conceptual concerns raised by photography, the practical advantages accorded to experiments on vision by photography will be addressed. Photographs were not only used as stimuli in experiments (as in stereoscopic vision) but the process of photography also provided methods for generating novel stimuli (as with composite faces) and analogies with the retinal activity.

Faces in depth

The first stereoscopes were constructed for Wheatstone in 1832 (see Wade, 1983, 1987, 2012). The initial published account of Wheatstone's stereoscope appeared in a book on human physiology by his colleague, Herbert Mayo, in 1833; Wheatstone had made mirror and prism stereoscopes as early as 1832, but he only described the mirror version in his classic memoir (Wheatstone, 1838). His first stereoscopes were made by the London optical instrument firm of Murray and Heath. The more popular model with paired half lenses was devised by Brewster (1849) and referred to as a lenticular stereoscope. Brewster (1851) also illustrated a wide variety of methods for combining stereo-pairs, as did Dove (1851). The optical manipulation of disparities was also achieved with Wheatstone's (1852) pseudoscope, which reversed them, and with Helmholtz's (1857) telestereoscope, which exaggerated them. The anaglyph method, enabling overprinted red and blue images to be combined through similarly coloured filters was introduced by Rollmann (1853).

Wheatstone and Brewster (Figure 3) were well aware of Talbot's early researches on capturing images on light-sensitive paper. In 1836, both were guests of Talbot at Laycock Abbey, prior to the Bristol meeting of the British Association for the Advancement of Science, and they corresponded about the process thereafter. Talbot's paper negative process was made public in 1839, the year after Wheatstone's first article on the stereoscope appeared. In fact the term 'photographic' was first used by Wheatstone (Arnold, 1977) who immediately grasped the significance of photographing scenes from two positions, so that they would be seen in depth when mounted in the stereoscope. In his second memoir on binocular vision he wrote:

> At the date of the publication of my experiments on binocular vision, the brilliant photographic discoveries of Talbot, Niepce and Daguerre, had not been announced to the world. To illustrate the phenomena of the stereoscope I could therefore, at that time, only employ drawings made by the hands of an artist. Mere outline figures, or even shaded perspective drawings of simple objects, do not present much difficulty; but it is evidently impossible for the most accurate and accomplished artist to delineate, by the sole aid of his eye, the two projections necessary to form the stereoscopic relief of objects as they exist in nature with their delicate differences of outline, light and shade. What the hand of the artist was unable to accomplish, the chemical action of light, directed by the camera, has enabled us to effect. (Wheatstone, 1852, pp. 6-7)

Figure 3. Upper, a stereodaguerreotype of Charles Wheatstone (1802-1875) and his family, taken by Antoine Claudet. Lower, a stereocalotype of David Brewster (1781-1868), sitting beside a model of his lenticular stereoscope, probably taken by Thomas Rodger at St. Andrews.

In 1840, Wheatstone enlisted Talbot's assistance to take stereo-photographs for him; when they were sent the angular separation of the camera positions used to capture the two views was too large (47.5°) and Wheatstone suggested that 25° would be more appropriate. Klooswijk (1991) has reprinted a section of Wheatstone's letter to Talbot, and Klooswijk has taken stereo-photographs of the bust Talbot probably employed from camera angles of 47.5°, 25°, and 1.75°. Wheatstone also requested the assistance of the London photographer, Henry Collen, to take stereoscopic photographs of Charles Babbage; a single camera was used to take photographs from different positions because it was difficult to find two cameras that were optically equivalent. Collen (1854) described it thus:

> In 1841, when I was one of the very few who undertook to make use of Mr. Talbot's process, Mr. Wheatstone not only had the idea of making photographic portraits for the stereoscope, but at his request, and under his direction, in August of that year, I made a pair of stereoscopic portraits of Mr. Babbage, in whose possession they still remain; and if I remember rightly, Mr. Wheatstone has previously obtained some daguerreotype portraits from Mr. Beard for the stereoscope. (p. 200)

The reason for Collen's letter to the *Journal of the Photographic Society* was that Claudet (1853) had claimed to make the first photograph for the stereoscope. Wheatstone did not express a preference for metal-plated daguerreotypes or paper printed calotypes (or talbotypes as they were also called) but Brewster did. Comparing the two processes he made the astute prediction that the production of multiple copies from a single negative would act to the advantage of the calotype. The quality of Talbot's photographs was inferior to that of daguerreotypes, but Brewster (1843) championed the former, particularly for portraits, in terms of cost, portability and reproducibility:

> In point of expense, a Daguerreotype picture vastly exceeds a Calotype one of the same size. With its silver plate and glass covering, a quarto plate must cost five or six shillings, while a Calotype will not cost as many pence. In point of portability, permanence, and facility of examination, the Calotype picture possesses a peculiar advantage…. The great and unquestionable superiority of the Calotype pictures, however, is their power of multiplication. One Daguerreotype cannot be copied from another; and the person whose portrait is desired must sit for every copy that he wishes. When a pleasing picture is obtained, another of the same character cannot be produced. In the Calotype, on the contrary, we can take any number of pictures, within limits, from a negative; and a whole circle of friends can procure, for a mere trifle, a copy of a successful portrait. (p. 333)

It is likely that Wheatstone was the first scientist to take a photographic 'selfie' (in 1840); the first stereoscopic self-portrait photograph was probably taken by Edwin Emerson, a Professor at Troy University, around 1860 (see Wade, 2014).

Faces in rivalry

The many variations in positioning one or two cameras for taking photographs of faces to be viewed in a stereoscope must have resulted in unintentional binocular rivalry. These would have been considered as failure to produce stereoscopic effects. Here the interest is in intentional uses of photography to examine binocular rivalry. A paradox in the history of research on binocularity is that rivalry was examined experimentally before the involvement of retinal disparity in depth perception was demonstrated (by Wheatstone). Nor was the stereoscope the first binocular instrument, but the earlier ones were enlisted to examine the experience of rivalry rather than depth (see Wade & Ngo, 2013). Binocular single vision occurs when similar images are projected to corresponding parts of each eye. It can be difficult to distinguish between seeing two similar things and seeing their combination. No such doubts arise about binocular rivalry, which is one of the reasons why suppression theory has been so ardently supported. When greatly dissimilar images are presented to corresponding areas of each eye they do not combine, but compete. Binocular contour rivalry is more clear-cut than colour rivalry and the debate has been about whether alternation between whole eye views occurs rather than whether rivalry exists (Blake & Logothetis, 2002).

It was much easier to investigate colour and contour rivalry with the stereoscope. Wheatstone (1838) presented two circular patches of different colours or surrounded two letters by equivalent circles (to ensure binocular alignment) and noted the colour and contour rivalry that took place. Not only did he describe the alternation, but examined a stimulus variable (illumination) that could favour one stimulus over the other. One of those to take up the challenge posed by Wheatstone's work was Panum (1858). Not only did he introduce the concept of fusional areas that now bear his name, but he ushered in the stimuli that have been employed more than others for the study of binocular rivalry — orthogonal gratings. He remarked that gratings produced the strongest rivalry and that it was difficult to represent the ensuing changes: occasionally complete gratings were briefly visible but the dynamically varying, mosaic-like composites were seen most of the time.

Rivalry was so easy to induce with disparate drawings that it took some time for photographs to be introduced. They were used indirectly in trying to resolve the Chimenti controversy around 1860 (Wade, 2003) in which a pair of 16th century drawings were said to have been made for a stereoscope. Photographs of the drawings were a convenient way of making them widely available, but woodcut copies were used, too. Representations of realistic scenes were rarely employed in the early studies of binocular rivalry until photography was enlisted. The scientist who utilised photographic portraits to facilitate facial recognition and to make averaged (composite) faces was Galton (Figure 4).

Figure 4. *Ambiguous Galton* by Nicholas Wade; three perceptual portraits of Francis Galton (1822-1911). Left, a frontal face of Galton is framed in his profile. Centre, the left image is superimposed in green on the otherwise red frontal face; the halves appear in rivalry when viewed with red/green glasses. Right, a combination of left and right three-quarter views of Galton's portrait; the two aspects rival with one another.

The impetus for Galton's (1878a, 1878b, 1879) experiments on composite faces stemmed from presenting different photographic portraits in a stereoscope: "At first, for obtaining pictorial averages I combined pairs of portraits with a stereoscope, with more or less success" (Galton, 1908, p. 259). We do not know which photographic pairs he utilised, but he was investigating family resemblance at that time and might have used photographs of siblings, like those in Figure 5.

Figure 5. Galton's photographs of brothers (from Pearson, 1924) of the type he probably used for combining in a stereoscope. Rather than coalescing, they engaged in rivalry.

When Galton devised a method for making multiple exposures of different faces on a single photographic plate he dispensed with the use of the stereoscope. Similar stereoscopic combinations of different portraits were conducted independently at around the same time (1877) and communicated to Galton's half-cousin, Charles Darwin, who passed on a letter he received from A. L. Austin of New Zealand. Galton commented that the letter afforded: "another of the many curious instances of two persons being independently engaged in the same novel inquiry at nearly the same time, and coming to similar results" (1878b, p. 98). Austin's description concentrated on the blending of the two portraits whereas Galton drew attention to the rivalry between them:

> Convenient as the stereoscope is, owing to its accessibility, for determining whether any two portraits are suitable in size and attitude to form a good composite, it is nevertheless a makeshift and imperfect way of attaining the required result. It cannot of itself combine two images; it can only place them so that the office of attempting to combine them may be undertaken by the brain. Now the two separate impressions received by the brain through the stereoscope do not seem to me to be relatively constant in their vividness, but sometimes the image seen by the left eye prevails over that seen by the right, and *vice versâ*. All the other instruments I am about to describe accomplish that which the stereoscope fails to do; they create true optical combinations. As regards other points in Mr. Austin's letter, I cannot think that the use of a binocular camera for taking the two portraits intended to be combined into one by the stereoscope would be of importance. All that is wanted is that the portraits should be nearly of the same size. In every other respect I cordially agree with Mr. Austin. (Galton, 1878b, pp. 98–99)

The purpose of combining different portraits was not to investigate binocular rivalry but to derive some composite average of human types. Nonetheless, it is clear from Galton's description that rivalry did occur and it was for this reason that composite photographs were preferred. Paired photographic stimuli did not have the impact on studies of binocular rivalry than was the case for stereoscopic vision.

Faces and bodies in motion

The art of painting essentially excluded the dimension of time and therefore motion: a static view of a dynamic scene was captured. When motion was conveyed in a painting it was either inferred from posture or from conventional tricks that were plied by artists (Cutting, 2002; Gombrich, 1982). Studies of the duration of vision were to transform art by introducing motion via a rapid sequence of still images. The phenomena of visual persistence had been described by students of vision for over two thousand years, but it was only in the 19th century that visual motion could be harnessed by scientists and artists (Wade, 2004). It was a revolution in the literal sense because the instruments that initiated the transformation involved rotating discs.

The 1830s saw transformations in experiments on and representations of motion as well as space. In the same year (1832) that Wheatstone constructed mirror and prism stereoscopes, Plateau in Belgium and Stampfer in Austria made rotating devices for presenting a series of still pictures in rapid succession (Dorikens, 2001; Nekes & Kieninger, 2015). Their descriptions of the instruments were published in the following year. Plateau (1833) called his device a phenakistiscope and Stampfer (1833) referred to his as a stroboscopic disc; both consisted of discs with evenly separated slits near the circumference so that drawings on the opposite side would be seen in succession when viewed through a mirror (see Herbert, 2000; Mannoni, 2000). The instruments of Plateau and Stampfer could be used by just one person at a time, whereas in Horner (1834) developed a variant for group viewing: it consisted of a cylinder mounted on a vertical axis, with slits at regular intervals, and a sequence of drawings on the opposite inside surface of the cylinder. The apparent motion could be seen by several observers at the same time. Horner wrote: “I have given this instrument the name of *Dædaleum,* as imitating the practice that the celebrated artist of antiquity was fabled to have invented, of creating figures of men and animals endued with motion” (1834, p. 37). It became widely used in the latter half of the nineteenth century under the name of zoetrope.

As with stereoscopes, the initial images were drawn or painted as there were no alternatives available. This was to change with the announcement of photography at the end of the decade but the attraction of photographs as stimuli was quite different for simulations of space and motion. Wheatstone was immediately enthusiastic about the use of paired photographs rather than drawings for use with the stereoscope. They took away the tedium (and errors) associated with drawing a scene from two different positions and placed in their stead two slightly different but precise optical projections of the scene, captured by a single camera moved from one position to another. This satisfied the desire for realistic representations of three-dimensional scenes.

Plateau’s initial images for the phenakistiscope consisted of drawings of a pirouetting dancer and Stampfer’s were of dancers, marching soldiers or geometrical shapes. To the astonishment of observers a single figure appeared in motion: perceived movement was synthesized from a sequence of still pictures. However, when the instruments were manufactured (by Ackermann in London and Trentsensky & Vieweg in Vienna) the commercial potential of creating fantastic scenes in apparent motion was quickly appreciated – faces could metamorphose and heads could roll. Impossible worlds could be created and set in motion rendering the attraction for realism minimal. It was only in the 1850s, with attempts to marry the phenakistiscope with the stereoscope, that paired photographic images were seen as offering an advantage for synthesizing motion in depth (Wade, 2012).

Photographs of moving faces were employed by Purkinje after he made a variant of a phenakistiscope in 1840; he called it the phorolyt or kinesiskop (Figure 6), and it was sold commercially as a magic disc (Matousek, 1961). Purkinje used his phorolyt to produce dynamic images of a range of natural movements generated from a sequence of static drawings and photographs. These varied from the pumping action of the heart to the walking movements of newts. Purkinje also used photographs of his own body in rotation for use in the phorolyt (Figure 6). This was particularly apposite since he had conducted many experiments on body rotation and vertigo (Wade, 2000, 2016). The possibilities of examining animal motion by means of sequences of images had been foreseen by Horner (1834) and put into practice by Purkinje.

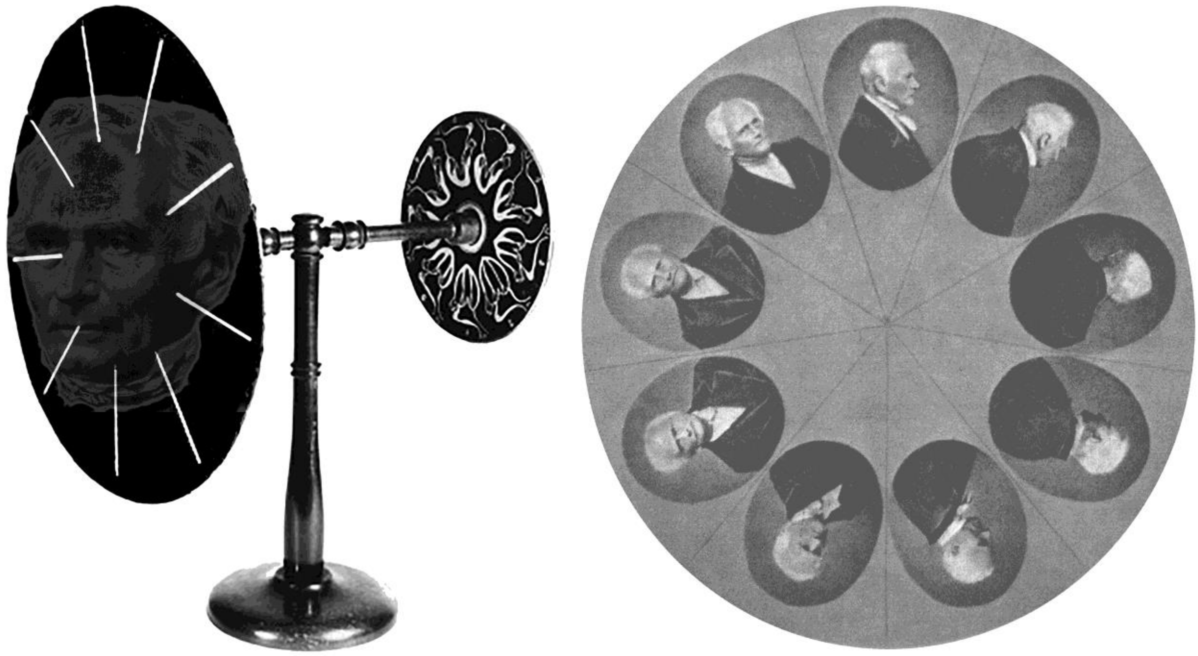

Figure 6. Left, *Purkinje's phorolyt or kinesiskop* by Nicholas Wade; the portrait of Jan Evangelista Purkinje or Purkyně (1787-1869) is superimposed on his model of the kinesiskop/phorolyt. Right, a series of photographs from 1865 of Purkinje rotating; they were arranged on a disc for observation in the phorolyt (from Psotníčková, 1955).

Purkinje was well aware of the advantages that sequences of photographs could provide for science: "… in the field of physiology, the motion of the heart, the blood circulation, the nerve currents, the muscle activity; in natural history, the movement of various animals on the ground and in the air, the most diverse play of colors, physiognomic expressions on the human face, dramatic motions, the growth of plants and other organic bodies, figurative representation from all sides, which otherwise is not possible to execute on a simple plane" (Purkinje, 1865, p. 657). Purkinje adopted these procedures in his studies of facial expressions.

Purkinje's idea of combining sequences of photographs was to bear fruit later in the century, when Muybridge (1887) and Marey (1873, 1879, 1895) studied the dynamics of biological motion with the aid of sequenced photographs. Both Muybridge and Marey used phenakistiscopes and zoetropes in their investigations but sequences of photographs could also be presented with the praxinoscope (see Wade, 2015). In 1879 Muybridge modified Plateau's phenakistiscope to view the sequences of photographic images mounted around the circumference of a disc, so that they could be projected via a magic lantern onto a screen; he called it a zoöpraxiscope. Having photographed actions (mostly of horses and humans) with a battery of up to 24 cameras, the images were hand drawn from the photographs onto transparent glass (see Brookman, 2010). Muybridge's theatrical performances of bodily movements were delivered around the world to audiences eager to see simulated motion of realistic subjects. Muybridge published his eleven volume *Animal locomotion* in 1887; it consisted of plates with sequences of photographs of humans and animals in motion; volume 8 was concerned with abnormal movements of males and females.

Marey adopted a more scientific approach to capturing motion. He wrote "Motion is the most apparent of the characteristics of life; it manifests itself in all the functions; it is even the essence of several of them… The most striking manifestation of movement in the different species of animals is assuredly locomotion" (1879, pp. 27 and 102). His interests were in the physiology of biological motion and his desire was to provide quantitative techniques for investigating it. To this end he sought to reduce dynamic actions to their static components. Initially Marey applied his graphical method which recorded activity and motion with the aid of ingenious devices he invented. The use of instantaneous photography was in the air when Marey's *La machine animale* was published (1873): some of his scientific acquaintances were discussing the possibility of studying bird flight in this way (Mannoni, 2000). Marey developed two photographic methods to record animal motion. One involved recording activity on a single photographic plate and the other recorded separate images of the action; they were called chronophotographs. His description of the process was: "Since the object of chronophotography is to determine with exactitude the characteristics of a movement, such a method ought to represent the different positions in space occupied by a moving object, *i.e.* its trajectory, as well as define the various positions of this body on the trajectory at any particular moment" (1895, p. 54). Both methods consisted of shuttering mechanisms on the camera; the first produced multiple exposures, and a photographic rifle was invented for the second. A rotating disc exposed different images in rapid succession. Twelve images could be taken in 1 second so that complex actions, like the flight of a bird, could be fractionated in time. A great advantage of the photographic rifle over Muybridge's method was that the action to be recorded was not confined to an arbitrary location; even the flight of birds could be filmed, and this was the subject of Marey's first forays with his rifle, in 1882. He even made models of birds in flight so that they could be viewed in a large dædaleum/zoetrope in order to simulate their movements. The shortcomings of paper negatives for recording such short intervals were overcome by using celluloid film. A pioneer investigator of animal locomotion noted: "It is impossible to over-estimate the value of instantaneous photography in recording animal movements. It has quite superseded every form of registering apparatus" (Pettigrew, 1908, p. 1111).

Face perception

Faces not only fascinate us but they also provide vital clues to identity, character, mood and social interactions. Artists have tried to capture this fascination since the dawn of depiction; scientists since the time of Aristotle have tried to classify character on the basis of facial form and expression. Writers like Porta (1586) and Lavater (1772, 1800) considered that character was expressed in facial form and that features of human heads showed marked resemblances to those of animals and they referred to the endeavour as physiognomy. This view was supported by many drawn illustrations like those shown in Figure 7. Some attempts were made to measure dimensions of the head and many reflected the influence of the artist Charles Le Brun (1619-1690) who took a more systematic approach to representing heads both full face and in profile (see Le Brun, 1751; Morel d'Arleux, 1806). In addition to depicting the expressions, as in Figure 7 left, he also drew simplified outline faces emphasising the configurations of the eyes, eyebrows and mouth. The prominent features of the schematic faces could be signified by horizontal lines and a vertical midline (as shown in Figure 12).

Figure 7. Passions and characters. Left, The expressions of anger, extreme despair and crying as represented in Le Brun (1750). Centre, Plate IV from Lavater (1800); the character types are given for 2-5; 1 is described as witty and religious and 6 is said to be courageous. Right, representations of the expressions rage, wonder and weeping, derived from Bell (1806).

Scientific interest became focussed on the muscles controlling facial expressions and Charles Bell (1806, 1844) displayed his artistic skills in representing them (Figure 7, right). Bell was an anatomist who appreciated the relationship between emotional expressions and their underlying anatomy: "Anatomy stands related to the arts of design, as the grammar of that language in which they address us. The expressions, attitudes, and movements of the human figure, are the characters of this language" (1806, p. vi). Bell had to rely on his eye and hand in depicting the facial expressions but Duchenne (1862) was able to advance the science of expression further by applying localised electrical stimulation to the regions over the facial muscles and by photographing the resultant facial state. Thus, Duchenne revolutionised the study of face perception by the use of photographs rather than drawings, as did Purkinje. Portraits of both scientists embedded in photographs they took can be found in Wade (2013). Despite the advantages afforded by photography, illustrated books of drawings on physiognomy continued to be published late into the nineteenth century.

Facial expressions

In *The Expression of the Emotions in Man and Animals* Darwin (1872) stressed the universality of emotional expressions in human groups. He drew upon the work by Bell as well as Duchenne's (1862) photographic studies of expression (George, 1994). Duchenne photographed faces of actors as well as others either stimulating the face electrically or simulating a variety of expressions. He considered that the expressions elicited by the electrical stimulation of specific muscles were too fleeting to be represented by the pen and that the camera provided the best means of capturing and communicating them. Duchenne was a neurologist who was following in the tradition of the physiognomists but he wished to place the analysis of facial expressions on more scientific foundations. He wrote:

> Photography, as a true mirror, can illustrate my electrophysiological experiments and help to judge the value of the deductions that I have made from them. From 1852, convinced of the impossibility of popularizing or even of publishing this research without the aid of photography, I approached some talented and artistic photographers. These trials were not, and could not be, successful. In photography, as in painting or sculpture, you can only transmit well what you perceive well. Art does not rely only on technical skills. For my research, it was necessary to know how to put each expressive line into relief by a skilful play of light. This skill was beyond the most dextrous artist; he did not understand the physiological facts I was trying to demonstrate. Thus I needed to initiate myself into the art of photography… I needed to photograph rapidly the expressions produced by the electrophysiological stimulus. At the time when most of my negatives were taken (1852-1856), the photographic apparatus in use was less perfect than those of today." (Cuthbertson, 1990, pp. 39-40)

Like others before him, Duchenne placed great importance on the muscles around the eyes, and the eyebrows in particular. He considered that the "muscles that move the eyebrows, of all the expressive muscles, are least under the control of the will; in general, only emotions of the soul can move them in an isolated fashion" (Cuthbertson, 1990, p. 43). The eyebrows are also a prominent feature in the expression of pain, as is shown in Plate 3 from Duchenne's book (Figure 8). The plate shows a variety of electrically stimulated and simulated expressions related to the state of the eyebrows. The paper masks were applied to the left and right sides of the face so that asymmetries could be examined in the photographs.

Figure 8. Plate 3 from Duchenne (1862) in which expressions of pain are shown.

At about the same time Purkinje was engaged in similar photographic investigations, but he was himself the subject who simulated and classified the facial expressions (Figure 9). Purkinje is said to have made 90 such photographs but only a small number of them have survived (Andel, 2004; Psotníčková, 1955). The photographs were taken around 1862 and nine of them were marketed in Prague in 1869, but Purkinje did not publish an account of them himself.

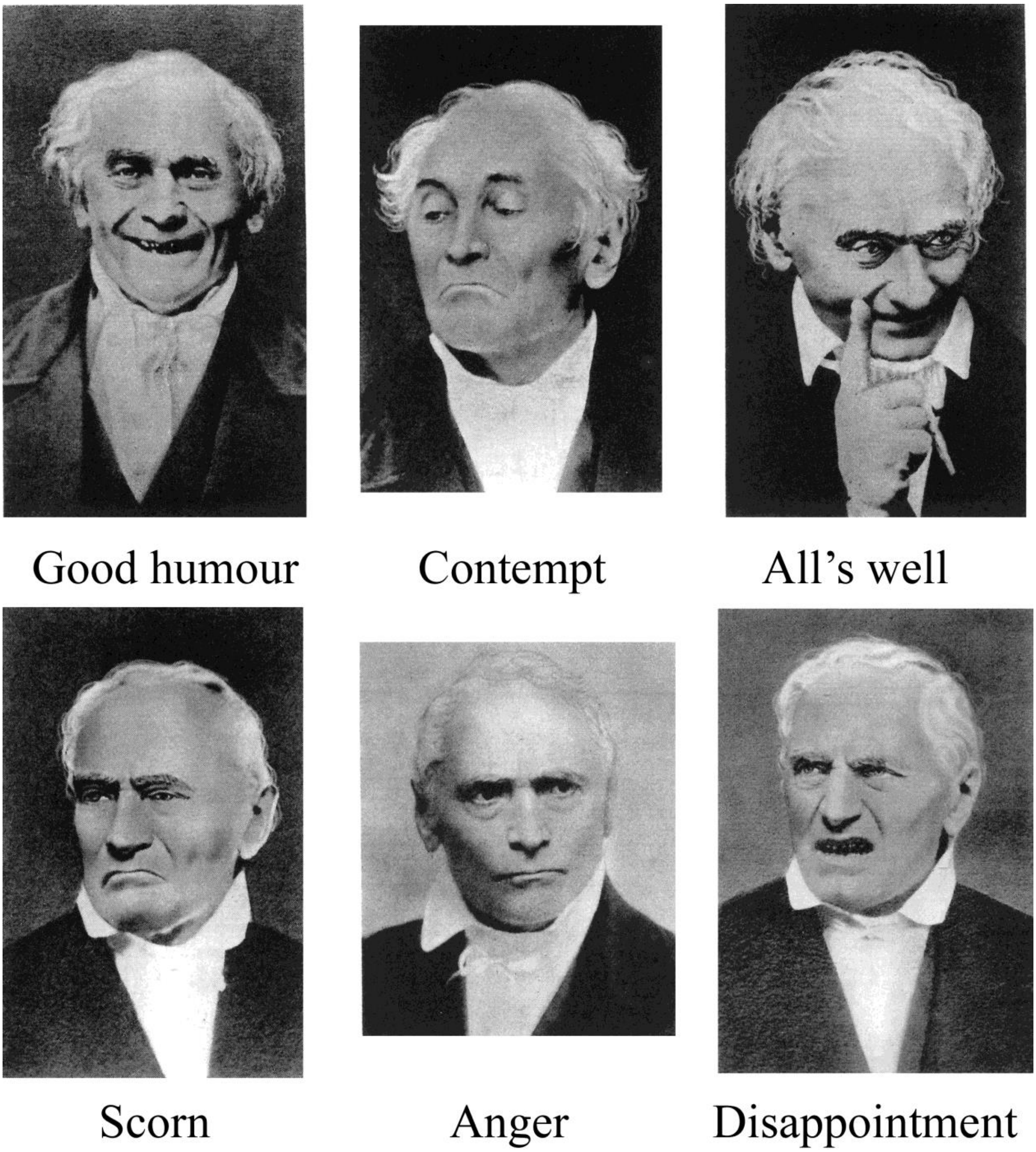

Figure 9. Six photographs of Purkinje with the expressions he considered that they represented (assembled from Psotníčková, 1955)

Duchenne’s photographs were used by Darwin (1872) who noted the similarity of human facial expressions and gestures to those of animals. In his study of expressions he drew extensively on the previous research of Bell (1844) and Gratiolet (1865) while disagreeing with their interpretations. Both had argued for distinctions between humans and animals whereas Darwin contended that there was continuity. In order to examine this continuity, he presented engravings of animals and photographs of humans. Gratiolet considered that all expressions are a consequence of the muscular actions attendant on responses to stimuli which naturally induce pleasure, pain, etc. Darwin said of Bell that “He may with justice be said, not only to have laid the foundations of the subject as a branch of science, but to have built up a noble structure” (1872, p. 2). Darwin reproduced illustrations from Bell (1844) and Duchenne (1862), but the photographs were redrawn. Of Duchenne he wrote: “he analyses by means of electricity, and illustrates by magnificent photographs, the movements of the facial muscles” (1872, p. 5). In his Introduction to the reprinting of Darwin’s book, Ekman noted: “No one today pays much attention to Gratiolet, Bell, or even Duchenne; almost everyone now studying the facial expressions of emotion acknowledges that the field began with Darwin’s *Expression*” (Ekman, 1998, pp. xxvii-xxix). Most histories of research on facial expressions tend to cite Duchenne as well as Darwin, but Purkinje rarely receives recognition.

Facial identity

In the same decade that Darwin’s book was published considerable efforts were being made to establish identity particularly in the context of the law. Many previous attempts had been made to facilitate facial recognition. For example, Le Brun (as shown in Morel d’Arleux, 1806) also made full face and profile drawings of the face with vertical and horizontal lines marking the significant facial features. A similar system was developed by Galton (1878a) who was among those who realised the benefits that photographing faces could provide for identification. At the 1877 meeting of the British Association in Plymouth he suggested that identity could be established if full-face and profile photographs were taken of the same person:

> It is strange that no use is made of photography to obtain careful studies of the head and faces… It might be a great convenience, when numerous portraits have to be rapidly and inexpensively taken for the purpose of anthropological studies, to arrange a solid framework supporting three mirrors, that shall afford the views of which I have been speaking, by reflection, at the same moment that the direct picture of the sitter is taken. He would present a three-quarter face to the camera for the direct picture, one adjacent mirror would reflect his profile towards it, another on the opposite side would reflect his full face, and a third sloping over him would reflect the head as seen from above… The result would be an ordinary photographic picture of the sitter, surrounded by three different views of his head. (Galton, 1878a, p. 97)

Galton did not provide an illustration of how his mirror system would be set up but Bertillon (1890) did produce an engraving of what he called ‘the English method’ for obtaining an approximation to a full face and a profile view in a single photograph (Figure 10). Bertillon (1881) developed a method that involved two separate photographs, one full face and the other profile.

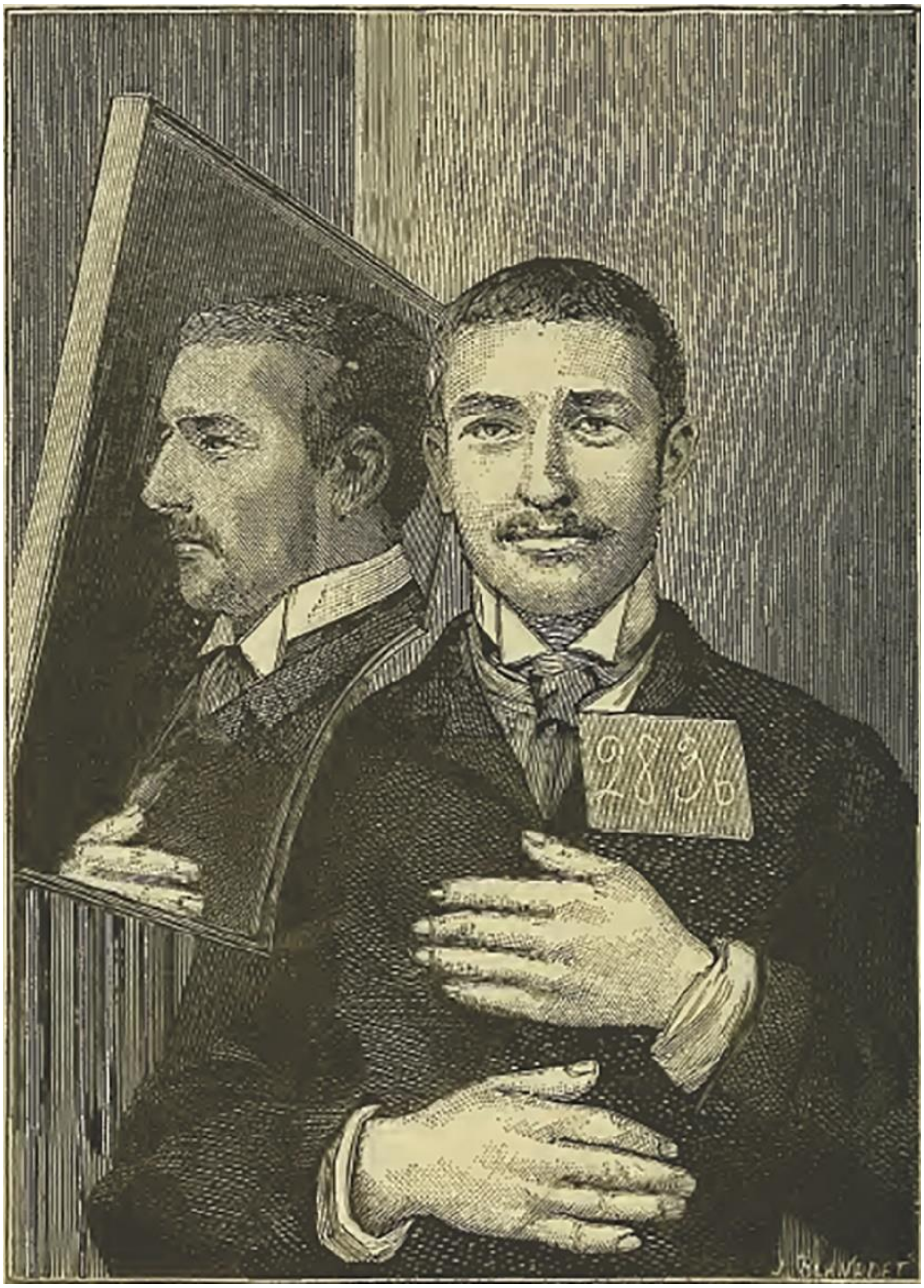

Figure 10. An approximation of Galton’s method for taking frontal and profile photographs of faces, as illustrated in Bertillon (1890).

Those singled out for such systematic sittings were criminals, and the system of such ‘mug-shots’ remains with us to this day. It was called judicial photography by Bertillon and it was used together with a wide range of other anthropometric measurements (Bertillon, 1881, 1890). He wrote: “The fundamental principle of judicial photography rests on the necessity of observing rigorous uniformity of pose and reduction, under conditions which we have been the first to define. The two poses chosen as being the most easy to reproduce identically are: 1st, the perfect profile, and 2nd, the full face” (Bertillon, 1896, p. 54). In 1883 his anthropometric system was adopted by the police in Paris and it became internationally popular thereafter. Like Galton and Purkinje before him, he relied heavily on fingerprints, too. In 1893 Galton visited Bertillon's laboratory in Paris and Bertillon’s photographs of him are shown in Figure 11.

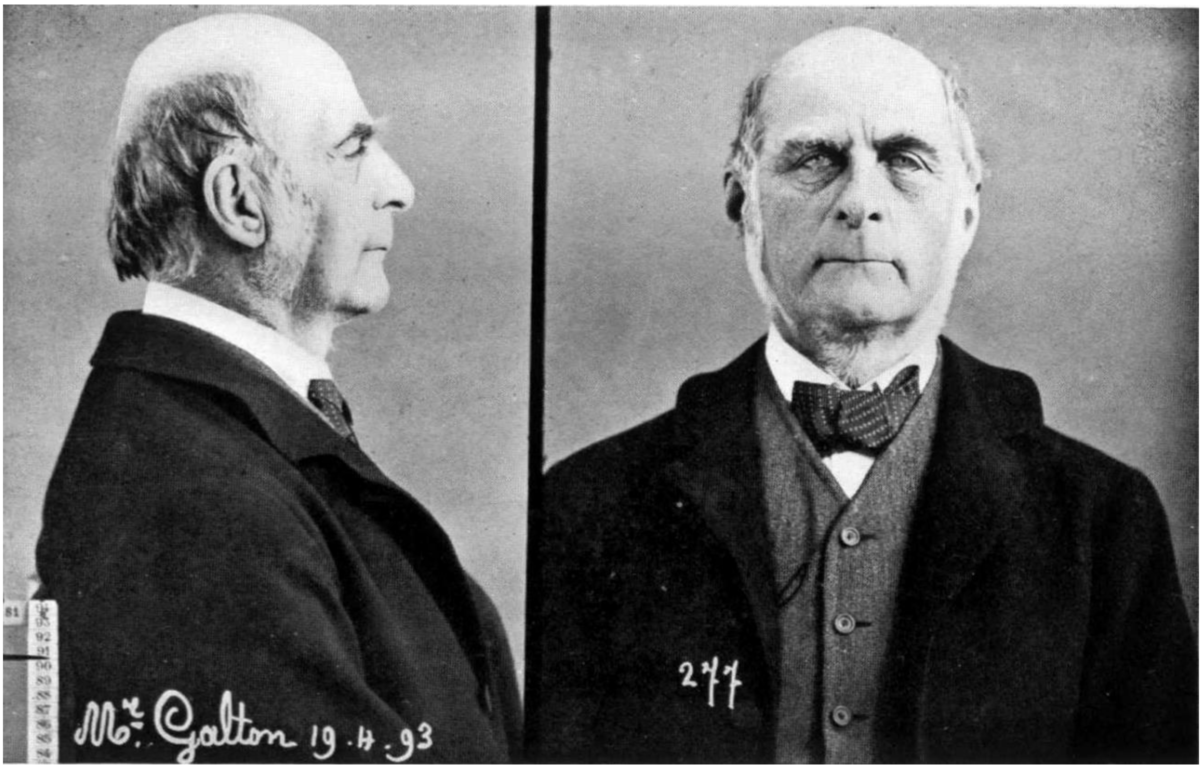

Figure 11. Francis Galton aged 71, photographed in Bertillon’s criminal identification laboratory (detail from Plate 52 in Pearson, 1924).

Photography transformed the ways in which face perception was studied. Facial expressions could be captured whether stimulated by electrodes or simulated by actors. The fleeting appearances could be related to the underlying musculature and the fanciful faces drawn by the physiognomists were replaced by more reliable and repeatable photographs. Composite faces could not have been conceived of, let alone realised, without photography. Galton sought to supply via composites the types that physiognomists represented with individual drawings. Galton also appreciated the power of photography in assisting facial recognition, but it was Bertillon who put this into widespread practice.

Composite faces

Whereas Bertillon’s judicial photographic method was designed to amplify individuality, Galton’s composite photographs aimed to remove it, reflecting the physiognomists’ desire to define type through facial characteristcs. Galton explored composite photography because of his dissatisfaction with stereoscopic combinations of different faces. He experimented with combining many faces as well as with photographing the face from different viewpoints. The method was proposed by Galton in his Presidential address to the Anthropological Subsection of the British Association for the Advancement of Science meeting held in Plymouth, 1877: “Having obtained drawings or photographs of several persons alike in most respects, but differing in minor details, what sure method is there of extracting the typical characteristics from them?... My own idea was to throw faint images of several portraits, in succession, upon the same sensitised photographic plate” (Galton, 1878a, p. 97). In a later article he wrote:

> … the photographic process of which I there spoke, enables us to obtain with mechanical precision a generalised picture; one that represents no man in particular, but portrays an imaginary figure, possessing the average features of any given group of men. These ideal faces have a surprising air of

> reality. Nobody who glanced at one of them for the first time, would doubt its being the likeness of a living person. Yet, as I have said, it is the portrait of a type, and not of an individual. (Galton, 1878b, p. 97)

Composites were produced by photographing a number of individuals (initially criminals) on a single plate:

> The first set of portraits are those of criminals convicted of murder, manslaughter, or robbery accompanied with violence. It will be observed that the features of the composites are much better looking than those of the components. The special villainous irregularities in the latter have disappeared and the common humanity that underlies them has prevailed. They represent, not the criminal, but the man who is liable to fall into crime. All composites are better looking than their components, because the averaged portrait of many persons is free from the irregularities that variously blemish the looks of each of them. (Galton, 1878b, pp. 97-98).

Galton was not able to reproduce the photographs in his *Nature* article (Galton, 1878b) but went to great pains to have the woodcut (shown in Figure 12, upper left) copied as carefully as possible from the composite (a) which is also shown in Figure 12. The method he used to align the facial features on the photographic plate was based on the register marks used by printers:

> I begin by collecting photographs of persons with whom I propose to deal. They must be similar in attitude and size, but no exactness is necessary in either of these respects. Then by a simple contrivance I make two pinholes in each of them, to enable me to hang them one in front of the other, like a pack of cards, upon the same pair of pins, in such a way that the eyes of all the portraits shall be as nearly as possible superimposed; in which case the remainder of the features will also be superimposed nearly enough. (Galton, 1878b, p. 97)

Galton's alignment technique is shown in Figure 12, as is a set of composite images of criminals. The alignment method employs markers that are very similar to the coordinates placed on faces by the 17th century artist Charles Le Brun, also shown in Figure 12. The photographs of the faces were then exposed for short duration in succession in order to produce the composite. For example, if the required exposure for a photographic plate was 20 s then each of ten faces required for combination would be exposed in succession for 2 s.

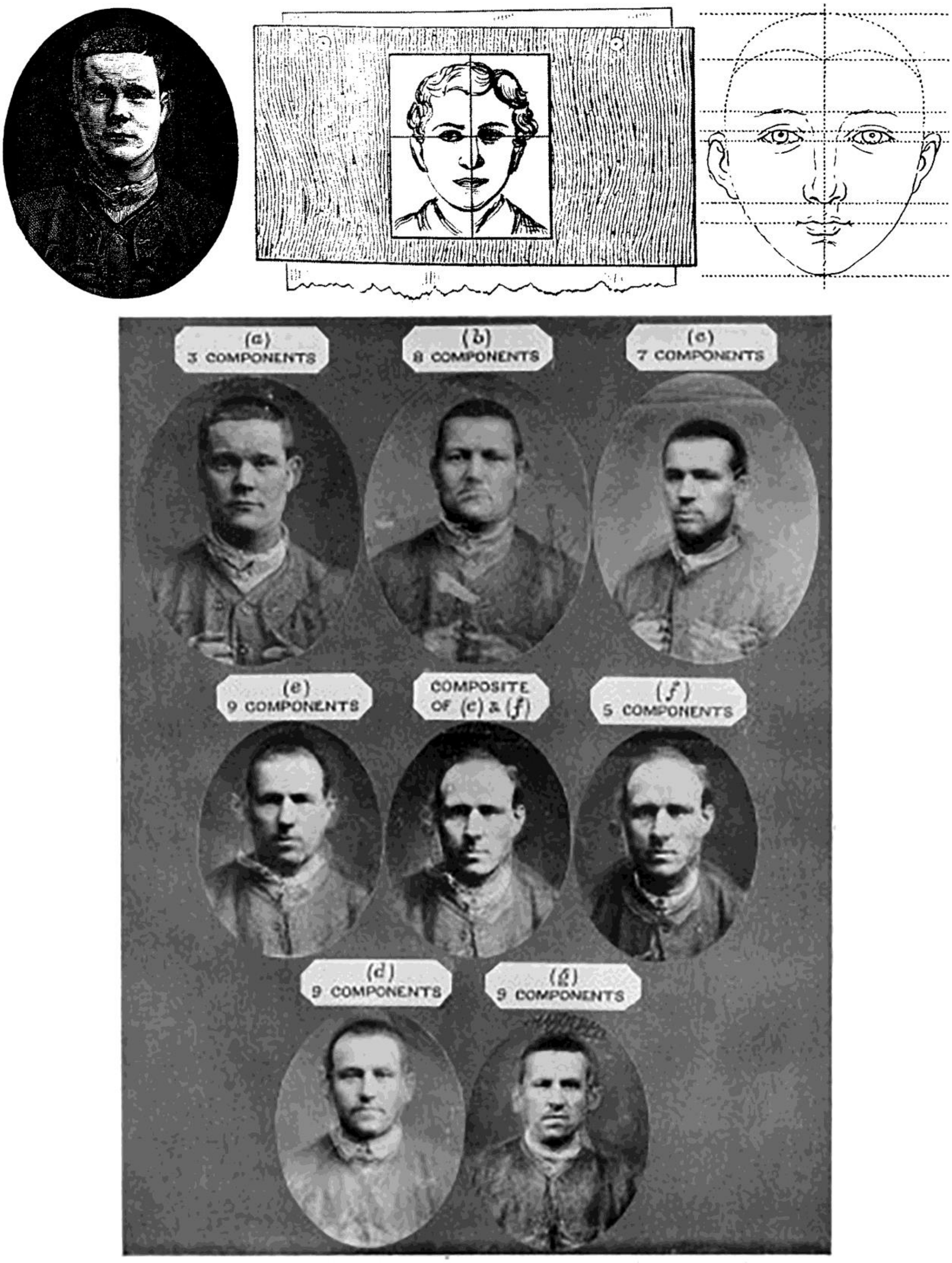

Figure 12. Upper left, the composite criminal and upper centre, Galton's alignment method (both from Galton, 1878b). Upper right, Le Brun's (1751) system of facial alignment showing the expression of tranquillity. Lower, Galton's composite photographs of criminals convicted of murder, manslaughter or crimes of violence (Plate 28 in Pearson, 1924).

The resultant composite images were always somewhat blurred and Galton compared this to the manner in which memories are stored: "Our mental generic images are rarely defined; they have that blur in excess which photographic composites have in some small degree, and their background is crowded with faint and incongruous imagery" (Pearson, 1924, p. 297).

Galton was constantly improving his methods and extending the groups he combined. These included patients in mental asylums, those with particular medical conditions, family members, racial groups and even portraits of historical figures. His biographer wrote: "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" (Pearson, 1924, p. 290). Galton used photography as a tool that could be added to the armoury of psychometrical methods. Whereas much of Galton's psychological research was concerned with measuring individual differences, composite photography was aimed at removing them so that generalities of type and character could be examined.

Faces fixed in the eye

From the onset of photography, writers speculated that images could be fixed in the eye as they were fixed on metal plates or paper. This, in turn, offered the possibility of providing clues to solve murders: the final face seen by the victim could be retained in their retina (Lanska, 2013). These speculations appeared to be given scientific support at about the same time that Galton was constructing composite portraits. Chemical and colour changes in the retina when exposed to light were demonstrated and they were related to the processes of photography. The red or purple appearance of the dark adapted eye of frogs and rabbits and their bleaching by light led first Boll (1876) and soon after Kühne (1877a) to propose that some substance in the retinal rods was modified by light and recovered in darkness. Boll is represented in red (Figure 13, left) because he observed the red colour in the dark-adapted eyes of rod-rich frogs. In his second article (Boll, 1877) he insisted that the colour of the retina that has been kept in complete darkness is 'red' and he called it 'visual red' (Wade, 2008a). Kühne, on the other hand, referred to 'visual purple' (Wade, 2008b) and he is represented in this colour in Figure 13, right. Kühne was fascinated by the similarities between the chemical processes in photographic films and in retinas: "the retina behaves not merely like a photographic plate, but like an entire photographic workshop" (translated in Wald, 1950, p. 98). In order to display this workshop in action Kühne exposed dark-adapted, living eyes (usually of rabbits) to light, sacrificed them and developed the retinas yielding what he called optograms – the final long-lasting stimulus (like a window) on which the eyes were fixed could be captured on the processed retina.

Figure 13. Left, Franz Boll (1849-1879) represented in red since he referred to the coloured substance in the retina of dark adapted frogs as ‘visual red’. Right, Wilhelm or Willy Kühne (1837-1900) is shown in purple because he gave the name ‘visual purple’ to rhodopsin.

Optograms

Kühne (1879) described optography in the following way:

> Just like the isolated retina, the retina in the eye of live or dead animals bleaches *in situ* only where the light strikes it. The effect is so completely local that if the images projected onto the fundus by the refractive media are sharp, they leave equally sharp, pale to colorless patterns on the purple surface of the rod layer, hence, photographs or *optograms*… One can readily obtain such pictures with somewhat fresh, excised rabbit or cattle eyes, by exposing them on the floor of a cylindrical container… To generate optograms *in vivo* it is best to use a windowless room containing a light-box illuminated from above. (Kühne, 1879/1977, p. 1297)

Kühne indicated that rabbits were the most suitable animals for obtaining optograms although he used frogs, too. They were immobilised and exposed to lighted patterns for between 10 s and 7 min then sacrificed and the retina was treated like a photographic film. Kühne illustrated the first optograms in 1877 and reprinted them in his long chapter on the chemistry of the retina (Kühne, 1877b, 1879); the images he produced from such procedures were fairly crude but did correspond to the objects presented prior to sacrifice. Kühne was also interested in human optograms and examined the eyes of patients who had died naturally (Kühne, 1877c). These could not yield optograms comparable to those from experimental animals because little control could be exerted on the objects that they viewed immediately before death. More notoriously, in 1880 Kühne processed the excised eye of an executed criminal, minutes after the guillotine had fallen. Notwithstanding the care with which Kühne prepared and treated the retina the image contained within it could not be related to any objects in his surroundings immediately prior to death: “A search for the object which served as the source for this optogram remained fruitless, in spite of a thorough inventory of all the surroundings and reports of many witnesses" (Kühne, 1881, p. 281 translated in Wald, 1950, p. 99).

Kühne's American colleague, William Ayres, pursued the possibility, proposed by Kühne, of capturing Helmholtz's portrait as an optogram and sending it to him as an acknowledgement of "the enormous advances his genius had made for us in physiological optics" (Ayres, 1881, p. 324). A large negative was placed over the eye of a rabbit that had been dark adapted for four hours; it was then exposed to sunlight and sacrificed. When the retina was processed there was little on it to suggest a face, let alone a specific person. It was not sent to Helmholtz. Ayres tried the experiment again with the decapitated head of the rabbit, with similar lack of success. He concluded: "that such an optogramme is impossible, and gave up the plan. I will also add that, since the above-described experiment failed so signally, it is utterly idle to look for the picture of a man's face, or of the surroundings, on the retina of a person who has met with sudden death, even under the most favorable circumstances" (Ayres, 1881, p. 325). The subsequent history of optograms indicates that negative evidence does little to dispel a good story!

Despite the need for long exposures and immobilised eyes, let alone the differences in rod distributions in rabbits and humans, the notion that there was scientific support that a retinal record at the moment of death would be retained captured the imagination of novelists and crime writers. On March 18th, 1878, *The New York Times*, under the headline 'The picture in a dead man's eye', reported: "It is, therefore, one of the undeniable verities of science that, under favourable circumstances, it would be a matter of no serious difficulty to identify a murderer by this process" (Anon, 1878). Similar sentiments were voiced in other newspapers and adopted not only by novelists but also by police investigators (see Evans, 1993; Lanska, 2013, 2014; Ogbourne, 2008). From Jules Verne onwards the possibility that the image of the murderer was retained in their victims' retinas was entertained.

Of all the scientific work Kühne performed, the notion of optograms had the greatest popular appeal, and they were applied in science fiction in a manner he distinctly disapproved of. While photochemistry was greatly advanced by the research of Boll and Kühne**,** the misuse of the latter's work on optograms cannot be considered to have performed a service for visual science. Kühne was partly to blame for this because he had incorporated the language of photography into vision. As Kremer (1997) remarked: "Kühne had added film to the camera-eye, or more precisely, an entire 'photographic factory in which workers upon command repeatedly prepare light-sensitive material for the film and simultaneously wipe out the old image'. The language and concepts of photography, for Kühne, became the language and concepts of optography" (Kremer, 1997, reprinted in Ogbourne, 2008, p. 69). Thus, the conceptual problems associated with the camera-eye analogy were amplified by associating photographic and retinal processes. One common problem with both analogies is that they require an unmoving eye. It is an irony of science that in the years Kühne was investigating optograms in rabbits and humans, studies elsewhere were indicating the instability of the eyes and the rapidity of their motions. In 1879, Ewald Hering demonstrated how the eyes moved irregularly, particularly during reading, and Émile Javal introduced the term 'saccade' to describe jerky eye movements (see Wade & Tatler, 2005). These were hardly the conditions to fix an image in the eye.

Conclusion

Photographs transformed the investigation of animal locomotion in general and face perception in particular Wheatstone saw the advantages that stereoscopic portraits would offer. Purkinje examined the face in apparent motion, albeit with regard to the rotating body. Duchenne photographed facial expressions following electrical stimulation or expressive simulations; Purkinje also captured his own facial expressions. Bertillon compiled full face and in profile photographs of criminals to assist in identification. Galton knitted several of these strands together; he commenced with combining photographs of different faces in a stereoscope before developing a novel technique of forming composite images of specified groups (initially criminals); he also proposed the system of frontal and profile photographs that was adapted by Bertillon. These researchers in facial perception are shown in Figure 14. All these techniques have provided a basis for contemporary computer manipulations of facial images.

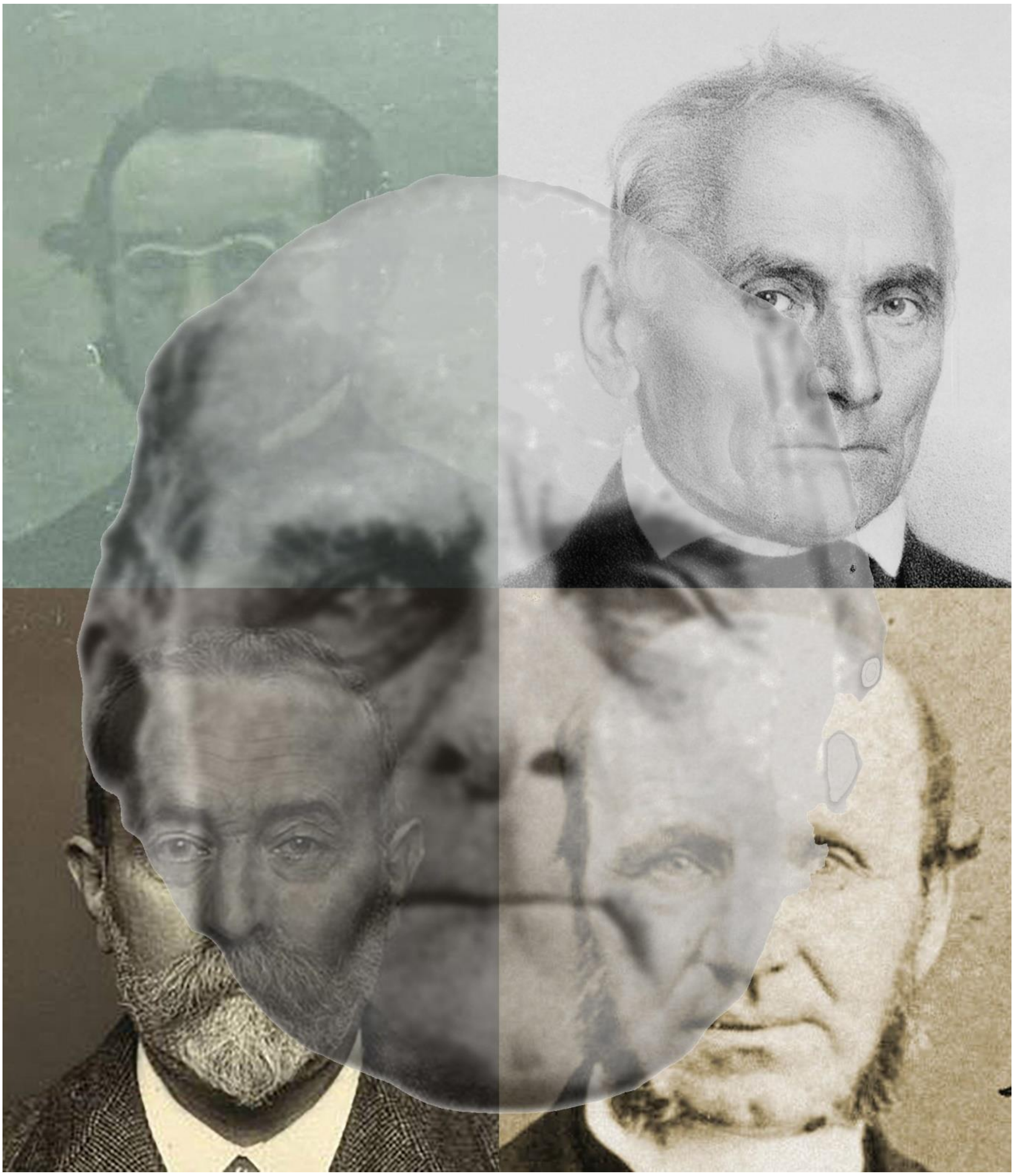

Figure 14. *Face detectives* by Nicholas Wade. Photographic portraits (clockwise from the upper left) of Wheatstone, Purkinje, Duchenne and Bertillon with Galton's face superimposed on them. The location of Galton's face corresponds to his method for aligning faces for composite portraits; the horizontal line passes through the eyes and the vertical bisects the frontal face.

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