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GALTON, FRANCIS (1822–1911) If any figure in the history of the behavioral sciences can be characterized as an original genius, it is Sir Francis Galton. He never held an academic appointment, yet he is rightfully claimed to be the founding father of differential psychology, of psychometrics, and of behavioral genetics. His creative efforts presaged almost all of the major theoretical issues under investigation in these fields in the twentieth century. Few scientists have had such wide-ranging and lasting impact.

Galton was born on February 16, 1822, at a country estate near Birmingham, England, the last of seven children (three boys and four girls) in a Quaker family of wealth, culture, and privilege. His father was a prominent banker and civic leader. His mother was the daughter of Erasmus Darwin, famous in his day as a biologist, philosopher, and poet—he was also the grandfather of Galton's illustrious half-cousin, Charles Darwin. Galton's paternal grandfather, a largely self-taught scientist, was elected a Fellow of the Royal Society for his research in optics and astronomy.

Before Galton was 3 years old, it was evident that he was a prodigy, since he had learned to read. At age 4 he was reading simple books and writing letters to relatives in a style that would do credit to a child twice his age, a fact that led the psychometrician Lewis TERMAN to estimate Galton's childhood IQ at near 200. As a preschooler Galton was already reading Latin and Greek classics, but when he was sent off to a private boarding school at age 8, he found it entirely uncongenial. He begged his parents to remove him. In his autobiography, written in his late 80s, Galton (1908) was still extremely critical of his early schooling: "I learnt nothing and chafed at my limitations. I had craved for what was denied, namely, an abundance of good English reading, well-taught mathematics, and solid science."

His parents wanted him to become a physician, following the footsteps of his eminent grandfather Erasmus Darwin. At age 16 Galton began the study of medicine, the first year at the Birmingham General Hospital, the second at Kings College Hospital in London, but only the basic-science aspects of medical education—chemistry, physics, mathematics, and physiology—captured his enthusiasm. He could envisage for himself a career in scientific research, not in treating patients. So at age 18, to prepare for a scientific career, he entered Cambridge University and majored in mathematics. A few months after Galton graduated from Cambridge, at the age of 21, his father died. Galton fell heir to an ample independent income from the family fortune and was freed from the need to earn a living for the rest of his life. He was immediately able to fulfill his long-held fascination with travel to remote places.

From this point on, Galton's long and immensely productive life can be divided into three main periods of intense activity devoted successively to exploration, research on individual differences and genetics, and the promotion of eugenics.

TRAVEL AND EXPLORATION (1844–1864)

For twenty years, Galton traveled extensively in Europe and the Middle East and published books and journals about his experiences. It was in Africa, however, that he won distinction as an explorer, geographer, and anthropologist. He extensively explored and mapped little-known regions of tropical South Africa and studied the physical and social characteristics of the people. One of his books based on his African explorations, *The Art of Travel* (1855), was a long-time popular bestseller in its day and went through nine editions. Great Britain's Royal Geographical Society awarded Galton its gold medal for his explorations, and his name is included among the famous explorers in British history—engraved on the granite facade of the Royal Geographical Society's headquarters in London.

During this period Galton also became engrossed by meteorology, to which he made original contributions. He was a pioneer in weather mapping and was the first to write weather reports for a daily newspaper, *The Times* of London. Also, he formulated a theory of cyclones and discovered the anticyclone. In developing better methods for predicting the weather by taking simultaneously into account a number of predictive indices, he invented a graphical form of what later, in algebraic form, became known as multiple-regression analysis.

INDIVIDUAL DIFFERENCES, STATISTICS, AND INHERITANCE (1865–1899)

This was the most productive period of Galton's career in science. His compulsive curiosity, mechanical ingenuity, mathematical bent, and theoretical inventiveness resulted in original contributions to meteorology, composite photography, graphology, fingerprint classification, anthropometry, sociology, education, genetics, psychometrics, and statistics. Whole chapters in books on the history of some of these fields have been devoted to his contributions (e.g., Stigler, 1986). Galton's accomplishments were recognized formally by his being awarded virtually every honor and distinction available to the most eminent personages of that period—knighthood, honorary degrees, fellowship in the Royal Society, and awards from many scientific societies.

In Galton's time, psychology was dominated by the philosophy and methodology of Wilhelm Wundt's psychological laboratory in Leipzig, Germany, which was mainly concerned with discovering the general laws of sensation, perception, and other mental processes, as measured by a variety of laboratory instruments (from which originated the phrase "brass instrument psychology"). Individual differences in these processes were of no interest to Wundt and his followers, however, who regarded this source of variation merely as a "nuisance" variable, to be minimized by averaging large numbers of measurements. Although Galton knew of the studies being done in Wundt's laboratory, he showed little interest in Wundt's theoretical aims, but he was impressed by Wundt's techniques for objectively measuring sensory-motor functions. Meanwhile, Galton's encounter with Darwin's *The Origin of Species* (1859), which he claimed had a greater impact on his thinking than any other book he had ever read, inspired his passion for understanding human evolution and human variation in both physical and mental traits. For the rest of his life, Galton was engrossed in studies of the biological basis of individual differences, proposing empirically testable theories, collecting enormous amounts of data, and inventing methods of measurement and statistical analysis that have mostly endured to the present. The individual differences that Wundt regarded as a nuisance variable were viewed by Galton as a paramount phenomenon for scientific study.

Galton well knew, of course, that natural variation among individuals of the same species is a crucial pillar of Darwin's theory of evolution. Individual differences in particular characteristics, based on genetic influence, constitute the raw material on which the process of natural selection works to effect changes in the course of evolution. A science of individual differences in human characteristics, Galton believed, would have immense social significance bearing on the future of human welfare. His interest focused mainly on individual differences in those mental abilities and personality traits he thought were most related to socially valued achievements. Thus, he launched the fields of differential psychology and its methodological basis, psychometrics (which measured those traits). Together they constitute one of "the two disciplines of scientific psychology" (the other is experimental psychology), as described by Lee Cronbach (1957) in his frequently cited presidential address to the American Psychological Association.

Galton's contributions in differential psychology are in some 65 of his more than 300 scientific publications. The fruits of his research on the topics most germane to the theory and measurement of intelligence were incorporated in two of his best-known books, *Hereditary Genius* (1869) and *Inquiries into Human Faculty and Its Development* (1883). His specific contributions in this domain are perhaps best summarized under the following headings of the contemporary fields they have most influenced.

Psychometrics and Statistics. Galton was never interested in the methodology of measurement and statistics for its own sake. All of his methodological contributions were merely incidental to the substantive questions that interested him. He quantified virtually everything. Galton's favorite motto was, "Whenever you can, count." He promoted the idea of objective measurement and quantitative analysis of data, whether by counting, ranking, or by true measurement. He held that objective measurement and the mathematical treatment of quantitative data were essential for a science of human variation; he applied this philosophy to most physical and mental characteristics that were within his power to count, rank, or measure. Thus, he originated a number of statistical and psychometric concepts familiar to present-day researchers.

One subject that interested Galton, for its obvious genetic implications, is the degree of resemblance between parents and offspring in various physical and mental traits; his efforts to research this question led to his methodological contributions best known today. As recently as the late nineteenth century no means existed for expressing, in an exact quantitative way, the degree of resemblance or association between two variables. No means existed by which one could precisely answer whether offspring are more similar to their parents in Trait X than in Trait Y. Galton began his study of parent-offspring resemblance in a precisely measurable trait—stature. He measured nearly 1,000 young adults and their fathers and mothers. (The height measurements were adjusted to remove sex differences by multiplying all female heights by 1.08.) The total range and shape of the distribution of height, as well as the overall mean height, were nearly the same for parents and offspring. It is obvious that individual offspring are seldom the same height as their parents, so Galton pursued how to represent precisely in quantitative terms the degree of resemblance between parents and offspring. He solved this by making a bivariate plot of the parent-offspring measurements, forming what we now call a *scatter diagram*.

He discovered that for his height project the data points formed an upward-sloping ellipse, which prompted the next step. After plotting the median height of all offspring who fell within each one-inch interval of parental height, he drew a single straight line closest to the center of this array of medians. The line was expressed mathematically as a simple linear equation, and its slope (or "regression coefficient") would serve as a precise measure of the degree of parent-offspring resemblance. Because the distribution of height was almost the same in parents as in offspring, when the axes of the scatter diagram were reversed and parents' medians were plotted within each 1-inch interval of offsprings' height, virtually the same line fitted the array of medians. The *slope* of the best-fitting line, which was the same in both cases, Galton referred to as the coefficient of co-relation (later spelled correlation). Thus was invented the concepts we now know as linear *regression* (i.e., the best-fitting straight line to the array of means in a bivariate scatter-plot) and *correlation* (i.e., the slope of the regression line when both variates are measured on the same scale and have the same variance.) Galton applied his methods to "parent" and "offspring" generations of size in sweet peas, with a result very similar to that for human height.

Galton was also interested in the degree of association between different traits measured on different scales and had to invent a way to express the correlations between them. This led to his invention of standardized measurements, that is, rescaling the original measurements to a common scale for all variables, known in psychometrics as *standardized scores*. The modern formulation of correlation, however, is attributable to Karl Pearson (1857–1936), a mathematician who greatly admired Galton and gave mathematically rigorous formulations to many of Galton's intuitive statistical conceptions. Pearson, known as the "father of mathematical statistics," was also Galton's chief disciple and a pioneer of *biometrical genetics.* Pearson wrote the most comprehensive biography of his hero: *The Life, Letters and Labours of Francis Galton* (3 vols., 1914–1930).

Other methods invented and introduced by Galton include: the scaling of mental test scores in terms of their percentile ranks within a specified population; the use of rating scales for nonmetric traits; scaling test scores and ratings in terms of the normal curve; use of the median and geometric mean as measures of central tendency in markedly skewed distributions; scaling skewed data by the lognormal distribution; and the ogive. Also, some of his ingenious quantitative analyses of data—though largely intuitive and lacking rigorous mathematical derivation—are the conceptual forerunners of *multiple regression, multiple correlation,* the *analysis of variance,* and *factor analysis.* The systematic development of these ideas were accomplished by mathematicians, mainly Karl Pearson and Ronald Fisher.

Behavioral Genetics. Galton was born the same year as Gregor Mendel (1822–1884); both of them, unknown to each other at the time, were pioneers in genetics, experimenting with peas as a means for investigating "natural inheritance." Both independently arrived at the conclusion that heredity is particulate, that is, traits are inherited via discrete elements (later called *genes*) that pass (for the most part) unchanged from generation to generation. Mendel made the greater contribution, since he discovered the fundamental laws of heredity—segregation, independent assortment, and dominance/recessiveness—whereas Galton never did. Mendel's success can be attributed to his propitious choice of phenotypes for his breeding experiments—several visible characteristics of peas (color [green or yellow] and form [smooth or wrinkled]) that were discrete, hence countable, and were determined (fortuitously) by single genes with no genetic linkage to other characteristics. Galton did his breeding experiments with peas merely as a convenient way of discovering things about genetics that might apply to human heredity, which are continuously distributed in the population, such as height and mental ability. He focused his study on a continuous trait in peas—their size (or weight)—which we now know is determined polygenically and to some extent environmentally. His data were too complicated therefore to reveal the fundamental rules discovered by Mendel. Nevertheless, Galton's studies revealed some important facts about polygenic inheritance. He discovered that the distribution of a polygenic trait conforms approximately to the normal curve in each generation, even when the parental generation is selected so as to have a markedly nonnormal distribution, and that, in the absence of selection, the variance of the trait was constant across generations.

Galton believed his most important discovery to be the phenomenon he first termed "reversion to the mean," and later, "regression to the mean." On finding the same phenomenon with respect to both physical stature and mental ability, he dubbed it *The law of filial regression to mediocrity.* This "law" simply quantified the observation that, in a given trait, offspring, *on average,* do not deviate as much from the mean of the population as do their parents. Of course, such regression toward the mean is simply a corollary of the imperfect correlation between parents and offspring—which is the more basic phenomenon. Hence, parent-offspring regression works in both directions: parents, *on average,* deviate less from the population mean than do their children. Although Galton's "law of regression" can be explained in terms of genetic theory, environmental factors and measurement error may also contribute.

Galton's "law of ancestral inheritance" has not survived in modern genetics. Neither Galton nor anyone else of that time fully understood the genetic mechanisms underlying "regression to the mean," which actually involves nonadditive effects (now known as *dominance* and *epistasis*) due to interactions among genes. In each generation the genes are simply shuffled, so to speak, and their interaction effects are redistributed at random. Thus, a parent who is exceptional in some trait because of propitious gene interactions may have an unexceptional child; and, for the same reason, an exceptional individual may have quite unexceptional parents.

Consider next Galton's most famous work, *Hereditary Genius* (1869), about which Charles Darwin remarked, "I do not think I ever in all my life read anything more interesting and original." It was the first attempt to study scientifically the inheritance of mental ability. As there were no validated intelligence tests at that time, Galton used as his criterion of mental ability the attainment of eminence in intellectual achievements. He began with a sample of some 400 historical figures—scientists, writers and poets, composers, statesmen, divines, judges, and the like—for whom extensive biographical data could be found in libraries (e.g., Aristotle, Newton, Goethe, Beethoven, Napoleon Bonaparte, Richelieu, and Disraeli). He labeled these individuals "illustrious." From biographical sources, he traced their direct-line ancestors and descendants as well as their collateral relatives (brothers, uncles, nephews), and determined the percentages of these groups who were at least distinguished enough by their achievements to be found in biographical directories. He labeled this level "eminent." Galton's two main findings were (1) a much higher probability of eminence among the genetic kinships of the illustrious than is found for persons selected at random from the general population; (2) the percentage of eminent persons decreases in a regular stepwise fashion the farther the degree of kinship is removed from the illustrious. Galton performed the same kind of analysis on champion athletes and obtained a highly similar result for athletic distinction.

Galton also introduced the *adoption method* for studying the relative effects of heredity and environment—"nature and nurture"—to use the phrase for which he is generally credited but which comes from Shakespeare (*Tempest,* IV, *i*). Noting that it had been customary in the past for popes to rear adopted sons, Galton found that their adopted sons, despite environmental advantages comparable to the natural sons of other illustrious men, did not show as adults anywhere near the same level of distinction as the biological descendants of the illustrious and eminent.

From his finding that the major distinctions of eminent relatives were often in a variety of fields (mathematics, literature, musical composition), Galton also concluded that distinguished intellectual achievements of any kind, or at least their hereditary component, are due to a *general* mental ability, which can be channeled by circumstance or interest into almost any kind of intellectual endeavor. This notion closely resembles the modern concept of *fluid ability* (and its associated "investment" theory of intelligence) formulated by R. B. Cattell in 1943.

The *twin study* method, which has figured most prominently in behavioral genetics, is also attributable to Galton. He was the first to note the importance of twins for determining the relative effects of heredity and environment, and particularly the significance of there being two distinct kinds of twins, *identical* and *fraternal,* or monozygotic (MZ) and dizygotic (DZ). Galton collected information on ninety-four sets of twins and studied their resemblances in many physical and behavioral characteristics, even their history of illnesses. He noted in examining the frequency distribution of *differences* between twins in various traits that the distributions are typically *bimodal,* indicating that there are two distinct types of twins. Since MZ twins are genetically identical and DZ twins are genetically no more similar than ordinary full siblings, Galton realized that a comparison of the correlation (r) between MZ twins with the correlation between DZ twins on a particular trait would indicate the degree to which genetic factors influence individual differences in the trait. Galton's insight is the basis for a commonly used formula in modern genetics for estimating the *heritability* (h^2) of a trait, in other words, the proportion of phenotypic variance in the trait attributable to genotypic variance: $h^2 = 2(r_{MZ} - r_{DZ})$. Summarizing his study of twins, Galton wrote:

> There is no escape from the conclusion that nature prevails enormously over nurture when the differences in nurture do not exceed what is commonly to be found among persons of the same rank of society and in the same country. My fear is, that my evidence may seem to prove too much, and be discredited on that account, as it appears contrary to all experience that nurture should go for so little (1883/1907, p. 172).

Theory and Measurement of Mental Ability. Galton never presented a formalized theory of intelligence, but it is clear from several of his publications, particularly *Inquiries into Human Faculty and Its Development* (1883/1907), that his conception of it can be summarized as *innate, general, cognitive ability.* The specification "cognitive" distinguishes it from the two other main aspects of mind recognized by Galton, the *affective* and the *conative*. He theorized that this general ability is a Darwinian fitness characteristic—hereditary—which developed through natural selection in the course of human evolution. He held that the distribution of intelligence in the population, like that of many hereditary physical traits, conforms to the normal, bell-shaped curve. His conception of ability as a normally distributed continuous trait represented a break with the typological thinking of his contemporaries; they viewed both genius and mental deficiency as distinct types of intelligence, separate from the general run, not the upper and lower extremes of a continuous distribution. Besides his hypothesis of individual differences in a *general* ability that is involved in all intellectual activity, he also recognized the existence of *special* abilities and talents but attributed less importance to them than to general ability in accounting for individuals' lifetime achievements.

Because all the contents of the mind enter through the sensory system and all expressions of mind depend on the effector system of motor nerves and muscles, Galton, arguing from evolutionary concepts, hypothesized that precise laboratory measurements of (1) human sensory acuity and discrimination and of (2) reaction times to the onset of a visual or auditory stimulus would afford an objective assessment of individual differences in the biological basis of general mental ability.

Galton invented an extensive battery of devices—various tests of sensory discrimination, reaction time, and memory span—with which to measure individual differences (described in his *Inquiries into Human Faculty*). In his Anthropometric Laboratory in the South Kensington Natural Science Museum, he and two assistants administered this battery of sensory-motor tests, along with a number of physical measurements, to nearly 10,000 people. He found that the sensory and reaction-time measurements seemed to show only very small differences between those classified into ability levels based on education and occupation; this was disappointing and Galton did not pursue this avenue further. Others did but with little more success at the time. It turns out, however, that Galton's original hypothesis was essentially correct; this fact remained unrealized in his time because of the generally low reliability of much of his data—especially that on reaction time (with a reliability coefficient of only .18)—and because appropriate statistical techniques had not yet been invented for determining the significance of his findings. When modern statistical techniques, such as the analysis of variance and multiple regression, were applied to Galton's original massive data, they confirmed his observations—that great overlap exists for the score distributions of the various occupational and educational categories and that the *average* differences (in the predicted direction) between these various categories appear almost negligibly small. It was also found that most of the average differences are statistically highly significant ($p<.001$), which in Galton's time could not be ascertained (Johnson et al., 1985). Today we know that the newer measurement techniques yield high precision and reliability for some of the simple variables of interest to Galton; they reveal low to moderate correlations with scores on modern psychometric tests of intelligence. Many of Galton's intuitive hypotheses have proved amazingly fruitful, although in his time the technical means for properly testing them was lacking.

EUGENICS (1900–1911)

Galton dedicated the last decade of his life to the advancement of *eugenics,* a term he coined for the study of genetics for the general betterment of the human species. In his autobiography (1908), written at age 88, he summarized his vision of eugenics:

> Man is gifted with pity and other kindly feelings; he has also the power of preventing many kinds of suffering. I conceive it to fall well within his province to replace Natural Selection by other processes that are more merciful and not less effective. This is precisely the aim of Eugenics. . . . I take Eugenics very seriously, feeling that its principles ought to become one of the dominant motives in a civilized nation, much as if they were one of its religious tenets (pp. 322–323).

He even wrote a utopian novel (*Kantsaywhere*) based on eugenics. A man of action, Galton founded a number of institutions to advance genetics and eugenics and used most of his personal fortune for perpetual endowments. (Although married for 44 years, he had no children or heirs.) He endowed the Galton Laboratory of Genetics at the University of London, the first of its kind; it remains a leading center of research in human genetics. He endowed a Professorship in Eugenics (now Genetics) at the University of London, which has been occupied by such luminaries as Karl Pearson, Sir Ronald A. Fisher, and Lionel S. Penrose. Galton founded and endowed two prestigious journals, *Biometrika* and *The Annals of Human Genetics,* which are still published. He also founded the Eugenics Society (recently renamed The Galton Institute), which publishes its own journal (*Journal of Biosocial Science*) and an annual symposium series on a wide variety of topics related to human genetics and eugenics (now more commonly referred to as social biology). He died one month short of age 90, on January 17, 1911. Few scientists have left such a diverse and lasting influence.

(*See also:* HERITABILITY; TWIN STUDIES OF INTELLIGENCE.)

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GENDER DIFFERENCES IN INTELLECTUAL ABILITIES The questions of whether, when, and how much females and males differ in their intellectual abilities have resulted in an enormous amount of hard feelings and controversy among researchers who have collected mountains of data in an attempt to answer these questions. Some tentative answers have emerged from all the data along with a clearer definition of the questions that still need to be answered. Although there is still a great deal to be learned about gender differences in the ability to think, learn, and remember, a gender-differentiated pattern of intellectual abilities has been found with females, on the average, performing better on a wide variety of cognitive tasks that involve the rapid retrieval of information from memory. Males, on the average, perform better on cognitive tasks that involve maintaining and manipulating information in short-term memory. It is also clear that a satisfactory explanation of these differences will involve an interaction of psychological, biological, and social variables. In interpreting these conclusions, it is important to keep in mind the fact that reports of "average" differences can be misleading because there is considerable overlap between the sexes in all intellectual areas.

WHAT ARE INTELLECTUAL ABILITIES?

Most psychologists think that intelligence is made up of numerous component abilities that are measured with performance on intellectual tasks. Some of these tasks are closely related, such as the ability to spell well and the ability to detect spelling errors in printed text; other intellectual tasks are more independent, such as the ability to hold an image in memory while deciding what it would look like if it were rotated in space (mental rotation) and the ability to generate synonyms for words. There have been numerous attempts