DARWIN, MENDEL, AND GALTON*

by

ROBERT PLATT

THIS paper was never meant to be a centenary address, in fact until I started to prepare it I did not realize that the original Darwin-Wallace communication to the Linnean Society was read in 1858. An interest in human genetics led me to seek more knowledge of the lives of the three men who seemed to me to have been the founders of our present understanding of heredity.

Darwin's evidence in favour of biological evolution, and his demonstration of natural selection as the force behind it, defined man's place in nature for the first time, as an organism which had evolved, and not as an act of special creation. Darwin, of course, realized that natural selection would not work unless the variations which nature selected were passed on by a hereditary process, but he had no idea whatever to the end of his life how that hereditary process worked. Francis Galton, who was his half first cousin (Grandfather Darwin having married twice) was the first to begin to study hereditary characters in the human subject in a scientific way, and made important advances in biometrics and in the statistical methods which were necessary to his studies, but he knew no more, when he was doing most of his work, about the process of heredity than did Darwin. And while the great men of the day were arguing about evolution and its implications, an obscure foreign monk, living in what we now know as Czechoslovakia, discovered the whole key to genetics, and without applying it to the problems of the time, and perhaps without even fully understanding its implications, retired again into the background.

This diagram (Fig. 1) shows in greatly simplified form the main points of

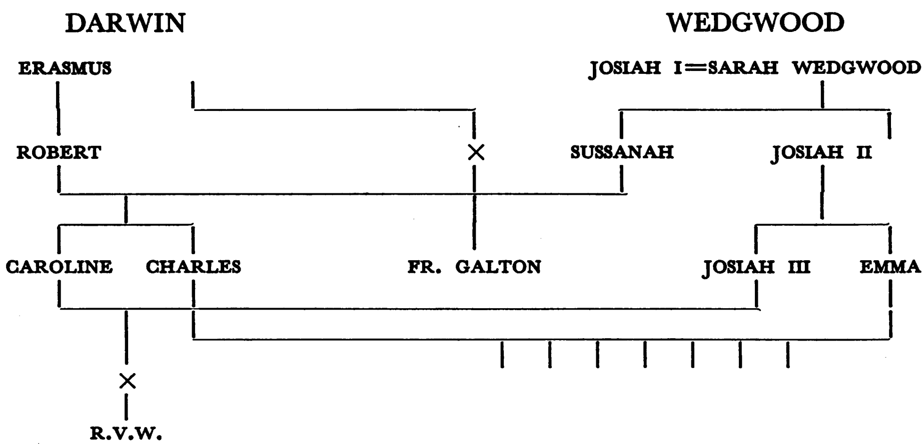

Fig. 1

* A paper read to the Osler Club, October 1958, and in slightly different form to Manchester University.

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interest in the family tree of the Darwins and the Wedgwoods, who intermarried so much. Here you will see how Charles Darwin and Francis Galton had a common grandfather in Dr. Erasmus Darwin and how one of the descendants of this gifted family was Ralph Vaughan Williams. Charles Darwin was born in 1809, into a world where education and opportunity seldom came to those without means. He inherited ability from the Darwins and from the Wedgwoods, and wealth from both, and during the whole of his life was able to live comfortably and bring up his seven surviving children without ever having to work for his living; but if his inheritance was fortunate, his environment during his childhood was certainly one of the factors calculated to produce the immature personality which Darwin undoubtedly was, and the almost continual state of neurotic invalidism from which he suffered later in life. His mother died when he was eight years old and his father, Dr. Robert Darwin, a successful practitioner in Shrewsbury, although greatly respected by Charles, was without doubt a very dominating personality who did not see in his son any spark of the genius to come. Indeed it is doubtful if Charles ever showed any sign of it at that age, unless a zest for collecting flowers, newts, and beetles could be so interpreted. Charles's elder sister Caroline, who was largely responsible for his upbringing after the death of his mother, was 'too zealous in trying to improve him', and Charles says that he remembers that when he would enter a room where she was he would think 'what will she blame me for now'. At school he seems to have been taught little but Greek, in which he made only poor progress, and was rebuked by his master for wasting his time studying chemistry and observing insects and birds. He was sent as a medical student to Edinburgh but found the lectures intolerably dull and had little taste for studying the medicine of the day. He says in his autobiography, which he wrote for the information of his children rather than for publication, that he gave up the study of medicine because he was convinced that his father would leave him well enough off to manage without earning his living. His father, still hoping to make something of him, proposed that he should go into the Church and sent him to Cambridge. This may sound a little strange, for there seems to be no doubt from the full edition of the autobiography which Lady Barlow has recently published, that Robert Darwin was himself an agnostic. Charles considered that most of his time in Cambridge was also wasted, at any rate the formal lectures which he had to attend. He liked Euclid but was unable to master other branches of mathematics. He attended Henslow's lectures on botany which were not part of his course of study. Henslow, who was incidentally a clergyman as well as a botanist, clearly recognized his ability, and in spite of the differences in their ages they became great friends. Darwin took a degree at Cambridge and the idea of the Church was gradually dropped and at about this time Henslow recommended him to Captain Fitzroy who was about to set out on the famous voyage of the *Beagle* and had offered to share his cabin with a young man who would go on the voyage (unpaid) as a naturalist. Robert Darwin disapproved of the idea, but Charles's uncle, the second Josiah Wedgwood, who always seems to have had a respect for the ability of his young

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nephew, persuaded his father to let him go. They waited at Plymouth for two months before the *Beagle* sailed: the weather was bad and Charles became depressed, and describes two characteristics which were to become typical of his later life, namely the development of neurotic symptoms and a determination not to let them interfere with what he really wanted to do. He was troubled, he says, with palpitation and pain around the heart, and having a smattering of medical knowledge was convinced that he had heart disease, but would not consult a doctor because he fully expected to be told that he must not go on the voyage and he was resolved to do so at all hazard. He was away for five years, from 1831 to 1836, and it is clear from his journal of the voyage of the *Beagle* that during that time he lacked nothing in courage or endurance, for he made long and hazardous journeys into the interior of South America on horseback. The object of the expedition was to complete the survey of Patagonia and Tierra del Fuego commenced under Captain King in 1826, and to survey the shores of Chile and Peru, and of some islands in the Pacific. Darwin's journal of the voyage of the *Beagle* is an amazing record of observations of natural phenomena of all kinds, the climate, geological formations, and the animal and plant life, but what is important for our present purpose is that Darwin saw these phenomena as something dynamic, as a process which was going on. He compared the animal life in one district with that in another, or in two islands, and he saw that environment favoured the development of one species or variety to the detriment of another: he pondered upon the forces which have caused so many of the great quadrupeds of former geological periods to have become extinct.

Darwin was already well versed in the geology of Lyell in which evolution as a geological process was recognized. He was familiar with Lamarck, who recognized an evolutionary process in biology and thought that a species improved by developing appropriate responses to its environment which it was able to pass on to the following generation. Lamarck had even gone so far as to hold that man himself was descended from some other species. Darwin's own grandfather, Erasmus Darwin, had written on evolution, as had also Buffon and Wells, and all this is acknowledged by Charles Darwin in his historical introduction to the *Origin of Species*. Wells clearly understood natural selection and Darwin's grandfather referred to sexual selection, the process which leads to mating and therefore to the selection of certain individuals to produce the next generation. Erasmus Darwin's work, however, seems to have been full of hypotheses with very few facts, almost the reverse of that of Charles who assembled his evidence with meticulous care. He spent much time studying the methods of horse breeders and pigeon fanciers. He wrote a book on the variation of animals and plants under domestication, and from his own observations, which started during his voyage on the *Beagle*, and which he continued later on, he gradually built up the evidence in favour of biological evolution until it was incontrovertible. In all animals and plants variations occur in nature and are handed down by a hereditary process. Far more seeds or eggs or embryos or young are produced than ever survive into adult life. Therefore those which do

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survive and reproduce the species are highly selected. A good deal of this selection is pure chance, but individuals possessing certain advantages will tend to have a higher survival value than others. The struggle for existence or, as Spencer called it, 'the survival of the fittest' acting over thousands of millions of years, could account for the adaptations which have led to the development and differentiation of species. Darwin, as I have said, had no idea of how variations were produced in nature or how the hereditary process worked.

In 1858 when Darwin (now aged forty-nine) had already been collecting his enormous masses of material and evolving his theories over many years (for he had already made a rough sketch of the book he was preparing as long ago as 1842), Alfred Russell Wallace wrote to him giving him an abstract of his theory of the evolution of species and their adaptation to environment by a process of natural selection. He had not accumulated nearly as much evidence as Darwin to support his thesis but, as Darwin said, many of his headings might have been chapter headings of the book which Darwin himself was planning, and indeed much of the argument is identical. What happened is now of course well known: Darwin, although he had been working twenty years on his subject, felt that he must give priority to Wallace, though to do so was a tremendous disappointment; but his friends Lyell and Hooker suggested that abstracts from his own manuscript should be read and published along with Wallace's paper in the *Journal of the Proceedings of the Linnean Society*, and this was done in 1858.

In November of the following year Darwin published *The Origin of Species*. He had planned a much larger work, but the Wallace episode had at last made him see the urgency of placing his conclusions before the world. In all probability this was something he had been unconsciously postponing, partly because of his dread of public controversy and partly because of his affection for his deeply religious wife, Emma Wedgwood.

Of *The Origin* Darwin himself says:

> It is no doubt the chief work of my life. It was from the first highly successful. The first small edition of 1250 copies was sold on the day of publication and a 2nd edition of 3000 copies soon afterwards. 16,000 copies have now (1876) been sold in England, and considering how stiff a book it is, this is a large sale.

If it is true that the scientific world was really ready to receive Darwin's message, and the educated man of the period so interested in science that he would buy *The Origin of Species* from the bookstall, why did it cause such violent and heated controversy? The theory of selection like that of evolution had been considered before. The difference of view between Darwinism and orthodox religion was in the question of how it was brought about, for as Darlington has expressed it in his recent broadcast, the theory of providential or guided or automatic progress was to be replaced by natural forces which had neither purpose nor goal.

> Instead of a spiritual guidance there is a material determinism in whose operation blind accident plays a small but necessary part. . . . The conflict between natural selection and automatic progress is much deeper today than the conflict between evolution and creation.

In the intellectual and emotional battles which raged at the time, Thomas Huxley and not Darwin was the main protagonist. Darwin remained withdrawn in his country house at Down. As William Irvine says: 'A portentous absence from crucial events which deeply concerned him was already making Mr. Darwin a legend.'

Of Darwin's own religious views we know something from his autobiography and from notes by his son Francis. He always tried to avoid the issue—perhaps again in order not to hurt the feelings of his wife in these matters—and when directly challenged, as he was in correspondence on occasions, he would reply that he had not given the subject the thought it merited. To Dr. Abbot, for instance, he says that bad health prevented him from 'feeling equal to deep reflection on the deepest subject which can fill a man's mind'. The full edition of his autobiography now available leaves us in no doubt at all as to his secession from orthodox religion of any kind. At the time of writing *The Origin*, he says, he would still have called himself a Theist, but after that his theism, with many fluctuations, tended to weaken.

It is not possible in the time at my disposal to say more of Darwin's other work and his general standing as a naturalist. In the course of his voyage he made observations on the origin of coral reefs and coral islands. He spent several years studying barnacles and wrote a book about them. He spent several years studying the fertilization of orchids and studying the variations in flowers and animals under domestication. The second book for which he is most famous is of course *The Descent of Man* which was published in 1871, but Darwin's claim to immortality stands or falls on *The Origin of Species* and, as we know from the views of biologists of the present day, it most certainly stands.

Before leaving Darwin for the time being I must briefly refer to the state of his health, which was a perpetual concern to himself and his close companions during a large part of his life. To the medical reader it is almost impossible to draw any conclusion but that it was psychologically determined. Darwin became ill in the year after his marriage and during his wife's first pregnancy, and was incapable of sustained work throughout the next two years. His devoted and over-protective wife practically gave up any kind of social life and in a few years they moved out of London to the country refuge at Down where they remained. As Douglas Hubble has said: 'The perfect nurse had married the perfect patient.' At Down, Darwin led a most regular life, breakfasting alone about 7.45 and working for about an hour and a half between 8 and 9.30. He would then come to the drawing-room for his letters, and if there were any family letters they would be read aloud to him as he lay on the sofa, frequently wrapped in his shawl. From 10.30 till about 12, or a little later, he would work again, but by that time he would consider his work done for the day and would go walking with his dog, wet or fine. He suffered very much from dyspepsia and from insomnia and periodically would go away to some hydropathic establishment for a cure. If you ask why I and others feel so sure about the psychological nature of his illness I suppose I should give a number of reasons. In the first place psychological illnesses so often take the form of dyspeptic symptoms.

Secondly, it is difficult to think of any organic illness which would go on for years without causing complications serious to life or permanently disabling; thirdly and most importantly, there is his own attitude towards his health, his preoccupation with it, his constant reference to it as the universal excuse for his not being able to appear in public or openly to defend his opinions. Darwin was a kind man, loved by his children, nearly all of whom subsequently suffered from neurotic symptoms and a preoccupation with invalidism. Mrs. Raverat has given us a beautiful description of her Aunt Ettie, Darwin's eldest surviving daughter, Henrietta. As a girl in her teens she had an illness, and the doctor told her to have breakfast in bed: this she did for the rest of her life. She wore a shawl at all times and would ring the bell for her maid to come and adjust it for her. But they were a happy family of kind, generous, unselfish, and tolerant people, who showed considerable indifference to what the world outside thought about them.

If we know a good deal about the Darwin family, we know little enough about the life of Johann Mendel. He was born in 1822 in the village of Heinzendorf in Silesia. His parents were peasants who had a small farm. He went to an elementary school where his teacher recognized his genius and the curriculum actually included some natural science, which was a most unusual thing at the time, and was described as a scandal by a school inspector. It was, however, encouraged by the local pastor, who took a great interest in the schoolboys of his parish and was himself interested in fruit culture and improving farm methods. Mendel's teacher urged his parents to send him later to Leipnik for further schooling, which they did at great personal sacrifice, for they were very poor and had to work under the old feudal law three days a week for the Countess Waldburg. After the school at Leipnik, Johann Mendel went to the district High School and lived under conditions of great hardship. His father was injured while working on the Countess's estate and was never able to work again on his farm. Mendel took a course for private teachers and was able to earn a frugal living. He went for a time to the Philosophical Institute at Olmütz, but felt that he could not endure these exertions further and that he was forced (to use his own words) to enter a profession in which he would be freed of the bitter necessities of life. He was received into the Augustinian monastery of St. Thomas in Altbrünn in September 1843, and took the name of Gregor, by which he is generally known. From the monastery he was sent for a time to the University of Vienna, where he continued his mathematical studies.

Although it is no doubt true that his devotion to scholarship and research determined the final choice of his profession there is no evidence that he was anything but a devout and exemplary monk; so much so, in fact, that he was elected abbot of the monastery in 1868. As a personality he is said to have been a kind, friendly, and smiling person though lacking nothing in determination. It seems likely that he died of hypertension because it is stated that he suffered from chronic kidney trouble for several years and also from heart trouble, and that an autopsy which he himself had requested showed no pathology other than inflammation of the kidneys and an enlarged heart. This was in 1884 in his sixty-second year.

The work of Darwin, as I have already said, was written for the layman as well as for the contemporary scientist, and is in leisurely if not somewhat laboured English, full of metaphors and footnotes. In his own words 'rather a stiff work'. To read Mendel's account of his experiments is a totally different experience. It is precise, factual, it says hardly anything except that which is necessary for the appreciation of his experiments and the recording of his results. Discussion is limited, or is practically limited, to remarks about the experiments of others, and why they had not led to precise results in the past. His work, which he had been doing for eight years, was communicated to the Naturforschender Verein in Brünn, at their February and March meetings of 1865, and was published in their *Transactions* in the following year. It is extremely difficult to get hold either of the original work or the English translation of it, which was made for Harvard University in 1925, but there is a copy of this translation in the British Museum. A Festschrift to commemorate the ninetieth anniversary of this work has recently been published by Luigi Gedda, and contains an Italian translation of Mendel's papers together with a facsimile of the German in his original handwriting. The German script is, however, difficult to read.

What exactly did Mendel do and how did he go about it? In the first place he discovered the laws of heredity as we know them today; a great deal of detail has since been added but his original work stands fast. What was supremely important was that he discovered that heredity was particulate and not blended. It consisted, the hereditary material, of a series of discontinuous factors which we now call genes, which are handed on unchanged from one generation to the next. Each new generation therefore contains a reassortment of characters inherited from its forebears. This immediately gives us the key to Darwin's difficulties, for if individuals were a blend of their parents, this should lead to uniformity and should not create new variations which Darwin realized were essential to the action of natural selection. Mendelian inheritance shows at once how new combinations arise, and by survival of those individuals which have favourable combinations of genes, there will gradually be built up a population better adapted to its environment than the population of previous generations.

Mendel's work was very largely done with plants and particularly with garden peas, but he also worked with bees. A good deal of this we know only through his correspondence with Nägeli. He calls his published work *Experiments in Plant Hybridization* and says that the subject is of importance in the history of the evolution of organic forms, and the only way to solve its problems is by detailed experiment. Indeed his success was entirely due to the careful planning of his experiments. He bought thirty-four varieties of peas from various seedsmen, and subjected them to a trial to make sure that certain characters which he intended to study would breed true. He spent two years over this trial, and found twenty-two varieties which remained constant and decided to study seven clearly cut differentiating discontinuous characters, for instance the form

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of the seeds, whether they were round or wrinkled; the colour of the seed coat; the form of the pods; the position of the flowers; and the length of the stem, that is, whether they were giant or dwarf plants. In all experiments the flowers were protected from foreign pollen; the hybridization was therefore completely controlled by himself and (and this is very important) the offspring of each plant was studied separately, whereas previous experimenters had taken the offspring of populations rather than of single plants. Reciprocal crossings were made, that is, male to female and female to male, in different varieties, and altogether he examined nearly 20,000 plants. There is not time to describe all Mendel's work in detail, and I must assume that the elementary laws of Mendelism are known to you. He found that the first cross, that is the F 1 generation between two varieties, gave rise to plants which were all the same and resembled one of the parents but were not a blending or intermediate form between the two. The character which showed he called 'dominant' to the other character which was in this generation completely suppressed and which he called 'recessive', but in the second generation breeding from these hybrids, the Mendelian ratio appeared of three showing the dominant character to one showing the recessive. Breeding from the dominant, one in three would breed true and give rise only to dominants, whereas the other two would give rise to the Mendelian ratio as before. He tried the back cross between the recessive of the F 2 generation and the hybrid of the F 1, and as he anticipated he got a 50–50 ratio for the offspring. He translated his results into the algebraic form $A+2Aa+a$, one pure dominant, two heterozygotes as we would now call them, and one recessive, and he then worked out his law of independent assortment by breeding from the F 1 generation and observing two characters, one of which might be called A and the other B. He showed that the two characters in the offspring both behaved according to his law but quite independently, so that the result was as if $A+2Aa+a$ were multiplied by $B+2Bb+b$. He then did the same experiment with three characters and found that the appropriate ratios occurred, only one plant out of every sixty-four showing the pure recessive form for all three characteristics. It is altogether one of the most beautiful pieces of scientific work ever written. It is purely mathematical, experimental, and factual, and avoids altogether speculation and wild hypothesis. With characteristic modesty Mendel concludes that it would be a good thing if others were to confirm his experiments, and he deduces that the variety produced by domestication is due to hybridization, which of course was precisely the clue which Darwin lacked, and he actually says that the transformation of one species into another may occur by artificial fertilization. Mendel does not say clearly whether he thought that his laws had universal application in plants and animals, he was far too cautious to do so, for he had not done the necessary experiments, but he implies that the animal world should be tested in the same meticulous way, and he himself had already started experiments with bees. It is very interesting to note that in these experiments he was studying not only physical characteristics such as colour, but also behaviour characteristics such as 'Stechlust' (literally Stingjoy—the aggressive tendency of bees). Thus he anticipated Galton, who was a pioneer in the belief that intellectual qualities as well as physical ones are inherited. Perhaps one cannot quite call Stechlust an intellectual quality.

Mendel was before his time: nobody took him very seriously. Even Nägeli, who was looked upon as one of the foremost botanists of the day, failed to see the importance of his work. There is no doubt that Mendel was disappointed, but it is perhaps questionable whether he himself saw the supreme importance of what he had done. Mendel's work was practically unknown in the world of science and biology until it was rediscovered about 1900, thirty-four years after its publication, and sixteen years after his death.

The story of the rediscovery is an interesting one. In 1900 three scientists, namely de Vries in Holland, Correns in Germany, and Tschermak in Vienna, all published researches on plant hybridization. It is usually reported that they all independently rediscovered the Mendelian laws, but as each one quotes the work of Mendel it seemed to me that it would be interesting to find out, if I could, how far they had gone with their own experiments before being enlightened by Mendel's genius. Incidentally, we know from a later paper by Tschermak that they discovered Mendel's work in a book by Focke published in 1881, which quoted Mendel without understanding his significance. Tschermak says that he first saw this in 1899. I have read these three papers in the *Berichte der Deutschen Botanischen Gesellschaft* of 1900. Certainly all of them had done experiments and had found at least some of the essential facts, but I think some doubt may have to remain as to whether they would have interpreted them correctly without Mendel's help. Tschermak, for instance, says that he started his experiments in 1898, and in the second year thought he had discovered something new when he came across Mendel's paper. It is clear from first principles that he could not have got very far with a botanical experiment on peas in two years. Perhaps we shall never fully know the answer to the question I have raised. Once you have been given the solution to a problem you can never tell how long you would have taken to solve it yourself. Most certainly credit goes to these three men, if only for recognizing the importance of what Mendel had done.

We know now, of course, that for all inherited characters in plants and animals, in fact in any organism which reproduces sexually, the Mendelian laws hold, though dominance and recessiveness are not always as absolute as they were in the characters which Mendel chose to study (as he knew himself), and multiple genes complicate the picture, and the law of independent assortment is modified by linkage. This in no way contradicts the laws of particulate inheritance which Mendel evolved. How extraordinarily pleased he would have been had he lived to know of the discovery of chromosomes and the cytological investigations which have since demonstrated visually the means by which his laws come about.

It is to me rather peculiar that Darwin's *The Origin of Species*, which showed that evolution depended upon the survival of the fittest, produced such heated controversy and the antagonism of nearly all the bishops of the day, whereas

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Mendel's work, which showed that the laws of heredity are the laws of chance, passed unnoticed, and is today acknowledged as a great piece of scientific investigation by the church in whose monastery the laws of chance as applied to heredity were worked out. The same church, in fact, whose influence had caused the Sorbonne to make Buffon recant on the possibility which he had entertained of one species being derived from another.

Mendel was the first botanist who seriously applied mathematics to his subject. Until the time of his experiments botanists worked by observation rather than experiment, or, if they experimented, as Darwin himself did in many cases, the results of their experiments were judged by observation rather than by calculation. This is unquestionably one of the reasons why Mendel was so successful, and probably one of the reasons why the world of natural science was not yet ready for his results.* I have already given reasons for thinking that in many ways the world was prepared, and well prepared, for the discovery of evolution, and of natural selection as its driving force. Wallace, if no other, had already come to the same conclusions as had Darwin, and if neither had lived, it seems almost inevitable that it would have dawned on the minds of scientists before very long, but for Mendel to set about a series of experiments which were going to take him eight years, and which were conceived in terms of the science of today rather than the science of his own time, was something quite extraordinary, which might not even have been done up to the present time if Mendel had not lived.

And now we must pass for all too short a time to Francis Galton who was born in 1822, the son of a wealthy banker. One of his grandfathers was Erasmus Darwin: his other grandfather was able to leave £12,000 a year between his three sons. Francis started medical studies in Birmingham and later went to King's College, London, to Cambridge, and finally to St. George's Hospital. He never finished his medical course, however, for the same reason that Charles Darwin never finished his, namely because his father left him a comfortable fortune and so, in his own words, 'He gave up all thought of being a physician'. Thus none of the three men of whom I speak today had to earn a living in the ordinary sense of the term. It may be that there is something to be learnt from this reflection. While at Cambridge Galton had a good training in mathematics, which was certainly important for his future, and which undoubtedly made his manner of thinking different from that of his cousin Darwin, but he never took an Honours degree in mathematics because his health broke down, and he gives, like Darwin, a description of symptoms which impress the reader of today as being certainly of psychological origin. Like Darwin again, he went abroad, first of all into Europe and thence to Malta and Egypt. In Egypt he decided to travel overland by camel to Khartoum. He returned to Britain, but in 1850 he planned an exploratory journey to parts of the interior of South Africa which seems to me to have shown tremendous courage and initiative. He financed it all himself and his description of this exploration is well worth reading. They had many dangerous adventures: some of their animals were killed by lions,

* I am indebted to Sir Eric Ashby for this point of view.

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and they had to make an uneasy kind of peace with the ignorant, savage, and warlike tribes. He returned in April 1852. In 1854 the Royal Geographical Society awarded him one of its gold medals, and in 1856 he was elected a Fellow of the Royal Society. From then until 1866 his writings show that he was becoming increasingly interested in heredity, and at that time he had another illness which he himself admits was of psychological origin.

Compared with Darwin and Mendel, Galton at first gives us the impression of being more of a dilettante. He was a man whose interests ranged far and wide over every topic of the day. He was given to experimenting with, and inventing, all kinds of instruments. He is known, of course, for Galton's whistle, which blows a note so high that the human ear cannot detect it although it excites dogs. He wrote on the art of travel, and lectured to troops who were going to the Crimea. He made meteorological maps and discovered anti-cyclones. He invented a heliostat for signalling by the use of the sun over long distances. He designed a wave machine to work ships, and an instrument to discover the height of clouds, and a sand-glass to be used as a bicycle speedometer: one simply counted the number of pedal movements made during the falling of the sand in the glass and this gave the miles per hour. He was the first to show the practicability of using finger-prints as a means of identification, having first demonstrated the three essential conditions, namely, that they did not appreciably vary with age, that they were unique to the individual, and that they could be classified.

Galton himself says that the publication of *The Origin of Species* was a crisis in his life and 'Drove away the constraint of my old superstition and gave me freedom of thought'. In his book on hereditary genius—and he uses the word genius more in the way that we would use the word talent or ability today—he collects a large amount of statistical evidence from families to show that mental and intellectual qualities as well as physical ones are inherited. He studied heredity in judges, statesmen, poets, painters, musicians, and divines. He attempted to work out the inheritance of physical qualities such as height and eye colour, and he elaborated the concept of the continuity of the germ plasm. He rejected the Lamarckian concept of the inheritance of acquired characteristics, which Darwin had to some extent accepted. He was a pioneer in the application of statistics to biology, and worked out the concepts of correlation and regression from the hereditary material he had collected, such as the size of peas and the height of humans.

He made a statistical examination of the efficacy of prayer, which was rather a bold thing to do in the nineteenth century, and showed that the lives of members of the Royal family, although they are prayed for every Sunday in all the churches in England, are statistically no longer than those of other people. He considered himself to be an agnostic, yet he had a religious type of mind and came from a family in which both Quakers and Catholics were represented. He looked upon the study of statistics as the key to the study of the obscure purpose of an unknown power. In this connection it is interesting that another famous Victorian had said: 'To study God's thoughts we must study statistics, for these are the measure of His purpose'—and that you may know was said by Florence Nightingale.

Galton was the first to realize the importance of the two kinds of twins in the study of genetics, for by comparing characters in identical and in non-identical twins, you could distinguish, as he said, between the effects of nature and nurture. He was greatly attracted to the idea of eugenics, for if domestic animals could be improved in a relatively small number of generations, so could the human race be improved if all possible encouragement were given to the better and more able members of the population to breed. For this reason he condemned the Catholic Church which for centuries had made its best scholars celibate and therefore sterile, while subjecting the free thinkers of society to martyrdom. But his outlook on eugenics was not one which looked forward to some sweeping and immediate change. He emphasized throughout the primary need for further study and the collection of material.

Although during his active period the work of Mendel was unknown to him, he was nevertheless one of the most important influences in the foundation of the modern study of human genetics. On the statistical side he was followed by Karl Pearson, the first Professor in the Chair which Galton endowed, and on the basis which these men built up, together with the discovery of Mendel, R. A. Fisher, and others have created a synthesis which is the science of genetics of the present day. Fisher is perhaps more than anyone responsible for this synthesis, and for the recognition that in the mutation process combined with sexual reproduction we have, as he says, a 'mechanism for the generation of a high degree of improbability'. Perhaps the Darwinian-Mendelian revolution in thought was slow to influence medicine, but in a society whose major ills were poverty, squalor, infection, exploitation, and cheap alcohol it was not unnatural that environment seemed to be a more urgent problem than heredity and evolution, and that the discoveries of Louis Pasteur, Robert Koch, and Lister had a more topical significance.

Now that poverty and serious infectious disease in Britain are all but conquered, we can see more clearly the interaction of heredity, natural selection, and environment in the great constitutional disorders which are now the main causes of death—arterial degeneration, high blood-pressure, and cancer. We can see cancer as a biological process, perhaps the inevitable result of cellular reproduction in an individual who survives for long enough. We can see how by natural selection the mortality from these partly hereditary diseases does not become significant until the post-reproductive period of life when nature is no longer interested in our survival. We can compare the results of somatic and germ-cell mutation in man with similar occurrences in domestic animals. In short we can see ourselves in better perspective in the animal kingdom, freed, as Galton said, from the constraint of our old superstitions.

Heredity and evolution are inextricably mixed and in the last 100 years seem to have gone through the three stages through which scientific theories sometimes pass, as Sir Cyril Hinshelwood said in his Anniversary Address to the Royal Society in November 1957:

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The first stage is that of gross over-simplification reflecting partly the need for practical working rules and even more a too enthusiastic aspiration after elegance of form. In the second stage the symmetry of the hypothetical systems is distorted and the neatness marred as recalcitrant facts increasingly rebel against conformity. In the third stage, if and when this is attained, a new order emerges, more intricately contrived, less obvious, and with its parts more subtly interwoven, since it is of nature's and not man's conception.

REFERENCES

BARLOW, N. (1958), *The Autobiography of Charles Darwin*, London, Collins.

CARTER, G. S. (1957), *A Hundred Years of Evolution*, London, Sidgwick & Jackson.

DARLINGTON, C. D. (1958), 'The Natural History of Man', *Listener*, 31 July, p. 161.

DARWIN, C. (1859), *The Origin of Species*, London, John Murray.

DARWIN, C. (1868), *The Variation of Animals and Plants under Domestication*, London, John Murray.

DARWIN, C. (1839), *Journal of the Voyage of H.M.S. 'Beagle'*, London, John Murray.

DARWIN, C. (1871), *The Descent of Man*, London, John Murray.

DARWIN, C., and WALLACE, A. R. (1858), *J. Proc. Linnean Soc.*, III, 45.

DARWIN, F. (1887), *Life of Charles Darwin*, London, John Murray.

DODSON, E. O. (1955), 'Mendel and the rediscovery of his work', *Sci. Monthly*, LXXXI, 187.

GALTON, F. (1869), *Hereditary Genius*, London, Macmillan.

GALTON, F. (1883), *Inquiries into Human Faculty*, London, Macmillan.

GALTON, F. (1908), *Memories of my Life*, London, Methuen.

GEDDA, L. (1955), *Novant'anni delle Leggi Mendeliane*, Rome.

HINSHELWOOD, C. (1957) *Nature*, CLXXX, 1233.

HUBBLE, D. (1953), 'The life of the shawl', *Lancet*, II, 1351.

IRVINE, W. (1955), *Apes, Angels and Victorians*, London, Weidenfeld & Nicolson.

MENDEL, G. (1925), *Experiments in Plant Hybridization* (English Translation), Harvard University Press.

PEARSON, K. (1914–30), *The Life, Letters and Labours of Francis Galton*, Cambridge University Press, 4 vols.

RAVERAT, G. (1952), *Period Piece: A Cambridge childhood*, London, Faber & Faber.