STANDING ON THE
SHOULDERS OF
DARWIN AND MENDEL
EARLY VIEWS OF INHERITANCE

DAVID J. GALTON

CRC Press
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Standing on the Shoulders of Darwin and Mendel

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Standing on the Shoulders of Darwin and Mendel

Early Views of Inheritance

by
David J. Galton

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Dedication

For: Jonah, Evan, Max, Alec, and Arthur

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Mendel as an abbot is entitled to design his own coat of arms. The description of these four panels is in the text page 109. Most bishops, including the Pope, have a personal coat of arms. They typically adopt, within the shield, symbols that indicate their interests or past services.

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The main characters

Charles Darwin (1809–1882) The great naturalist who proposed a theory of evolution of species by natural selection.

Gregor Mendel (1822–1884) A Catholic monk and priest who demonstrated a theory of inheritance in the edible pea.

Francis Galton (1822–1911) A young cousin of Darwin by 13 years who tested Darwin's theory of inheritance in rabbits with negative results.

Joseph D. Hooker (1817–1911) A botanist and director of the Royal Botanical Gardens at Kew. One of Darwin's best friends and advisors.

Thomas H. Huxley (1825–1895) A biologist and bulldog defender of Darwin's theory of evolution by natural selection.

Alfred R. Wallace (1823–1913) The codiscoverer of natural selection with Darwin.

George Romanes (1848–1894) Darwin's young student and research assistant.

Hugo de Vries (1848–1935) A botanist who rediscovered Mendel's theory. He developed his own cellular mutation theory to explain sudden changes in plant structure.

Carl E. Correns (1864–1933) A botanist who rediscovered Mendel's theory of inheritance.

Eric v. Tschermak (1871–1962) A botanist who re-discovered Mendel's theory of inheritance.

William Bateson (1861–1926) A biologist and bulldog defender of Mendel's binomial theory of inheritance.

Archibald Garrod (1857–1936) A doctor at St. Bartholomew's Hospital, London who found Mendelian ratios in his study of rare inherited diseases.

Karl Pearson (1857–1936) A student of Galton's, a mathematician and statistician who invented the Chi^2 test among others. He defended

Darwin's blending theory of inheritance during the Mendelian–Biometrician debate of 1904.

Walter F R Weldon (1860–1906) An Oxford zoologist who believed problems raised by Darwin's theories were purely statistical. A colleague of Karl Pearson and bitter rival of William Bateson in the Mendelian–Biometrician debate of 1904.

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Preface

This book is not written by a professional historian but more from the position of an experimental scientist for whom it is important to formulate the right questions, to design experiments that might be expected to answer them, to do experiments that ask the question of what would happen if..., to build a coherent framework of interrelated ideas, to see how they need to be tested; and then what to do with facts that go against them. This book shows how personal relationships help or hinder progress of such a research project.

More than dealing with the results and explanations of science this book deals with the drama of doing science. This often involves the anguish of going up dead-ends by working on wrong ideas and being unable to drop them when the evidence points in another direction. Or coworkers fall out because of rivalries, jealousies, egocentricity, and thwarted ambitions. Methods are used that are too insensitive to give the correct answer but tantalizingly point to a possible solution.

The text deals with historical characters, so the reader has a right to know which parts are biographical. The majority of events described in this book were taken directly from original sources such as autobiographies, letters, diaries, publications by the actual characters, and eyewitness accounts of public meetings, although not always presented in their strict chronological order. I have used the diary extracts mainly to illustrate the text and have not, therefore, included the dates when they were written.

Similar to many eminent Victorians, Charles Darwin, Thomas Huxley, George Romanes, and Francis Galton were very reticent about their personal lives; for example, it is very difficult to find any personal comments about the quarrel between Darwin and Galton as described in [Chapter 6](#) or the dispute between Romanes and Wallace in [Epilogue 2](#). It is impossible to catch the right tone of people one never knew with only incomplete records such as letters and diaries to go on. The closest intimate records I have used are the diaries kept by Galton's wife, his sister Emma Galton, and Charles Darwin's wife; but these in many ways are more interesting for what is omitted than their actual entries. The diaries mainly consist

of brief headings and notes written in shorthand for various topics such as births, marriages, travels, occupations, property, illnesses, and deaths. Darwin, Wallace, and Galton wrote autobiographies, mainly for posterity, and these have been used extensively. The wives of Romanes and Bateson published accounts of their husbands' lives, which have been frequently quoted.

Mendel came from a small farming village in a remote corner of Silesia in Eastern Europe. There are not many accounts of his life there. He took his vows as a monk at the age of 21 years and lived in his monastery until his death in 1884. His social life was considerably restricted. He published at least three scientific papers, known to have written at least ten letters to colleagues (whereas Darwin wrote more than 15,000 letters and Galton more than 450), and Mendel went abroad for the first time at the age of 40 to visit London. I have used his standard biography by Iltis (1924) referenced at the end of this book as well as other named texts there for many of the facts; other details come from the Mendel Museum in Brno. In respect for Mendel's ecclesiastical career as an abbot of St. Thomas, Brno I have selected as many chapter headings relating to religious texts as possible to reflect the topic of each chapter.

The story is mainly told through the eyes of Francis Galton (no relation to the author) because he was involved with the key players throughout his long life. He was an exact contemporary of Gregor Mendel both being born in 1822 and lived until 1911, so witnessing the foundations of modern genetics. Galton came under the influence of his cousin Charles Darwin from the start, which affected his ideas on heredity and my book begins at this stage. Galton and Mendel both presented their first observations on heredity in 1865. Galton's paper was titled *Heredity Talent and Character* published in the *Macmillan's Magazine*, and Mendel's was *Experiments in Plant Hybridization*. Both the titles give a clue to their different approaches to science. The former uses abstract words that are difficult to define such as talent and character, whereas Mendel tells you exactly what he did with plant hybrids—experiments. Comparing Mendel's work with the work of Darwin, Galton, Romanes, and Pearson like this reveals in its true light the genius of Mendel. Mendel unfortunately did not live to see his own work being accepted; he died in 1884. Galton subsequently played a significant role in the progress of genetics and lived to see Mendel's theory firmly established, following the Mendel–Biometrician showdown of 1904 in Cambridge, United Kingdom as described in [Chapter 15](#). He also appears to have recognized how close he had got to Mendel's interpretation with his own studies on plants (the sweet pea) and animals (Basset hounds).

This book would be thus characterized as an account of the investigations by Darwin, Galton, Mendel, Romanes, and others on the nature of heredity in the latter half of the nineteenth century. It is a mixture of the

story of science with a good deal of the methods used to obtain the results of science by observation, experiment, and logic.

The epilogues are much longer than usual and I have included other relevant ideas that do not fall easily into the main text by superscript numbers indicating a short note to be found at the end of this book. The sources of the most of the described events are given in a reference list of books and articles I have consulted at the end. There is also a gene timeline of events taking the reader up-to-date with the discoveries of the double helical structure of DNA, cracking the genetic code, and the completion of the human genome project.

My grateful thanks to John Harris, George Davey-Smith, John Walker-Smith, Gordon Ferns, Brian Shine, Tim and Jon Galton, David James, Robert Dudley, and Mary Seed for their patience and good humor for criticizing all or parts of the text. My debt is immeasurable to my teachers J.B.S. Haldane for genetics, J.Z. Young for evolutionary biology, M. Rodbell, Nobel Laureate 1994, for sharing his enthusiasm for scientific research, Russell Fraser for guidance in clinical medicine, and not least to my students without whom very little would have got done.

David J. Galton

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Prologue

...bald parents usually have bald children, grey-eyed parents, grey-eyed children and squinting parents have squinting children.

—Airs, Waters, Places. Hippocrates,
(c.460–c.377 BC)

We biologists have been from earliest times in great confusion about the mechanisms of inheritance. Our ideas up to the nineteenth century had not progressed much further than Hippocrates as quoted above. The views on heredity in the nineteenth century were still vague and contradictory and the subject had never been squarely faced by scientific experiment. There seemed to be no way of predicting which features of parents (eye color or squints) would be transmitted to their children and in what proportions. In some ways, this was very fortunate. It meant that there was a big problem waiting on our doorstep to be solved. Biologists in the nineteenth century still read Aristotle (384–322 BC) too much and relied on his authority that taught in his book *On the Generation of Animals* that inheritance with two sexes depended on their copulation and the growth of a preformed structure (a tiny homunculus) in the male seed. The male seed did not need to fuse with any female material for its development. The female menstrual blood may be needed to activate the male seed or the female may be just acting as an incubator. To believe in Aristotle is one thing—to grasp a new scientific idea is quite another. So, heredity was an area that many nineteenth century scientists thought important to tackle.

Was heredity an important problem? The biologists who took it up thought so and cared about it more than anything else in the manner of truly committed scientists. If we knew how it worked and when we learnt how to control and manipulate it, we may be able to change the whole future course of human development, altering and improving all the inherited features we pass on to our children. It was one of the burning issues of the time, and still is.

Not to exaggerate, the knowledge of how heredity works and our ability to control it would put man back at the center of his world again. Throughout history mankind is always being displaced from the center of the action. First, we were peripheral to God's unknowable purpose, kneeling in the great medieval Cathedrals to worship his works of creation. In the Renaissance, we recovered our sense of importance, as man became the measure of all things. In the Enlightenment, we learnt to question the authority of Plato, Aristotle, Galen, and others to go to look for ourselves. Then the new cosmology placed us on a wandering planet, one among billions, as tiny specks of life with no more of significance than an atom of cosmic dust. Now, we may be suddenly able to rise from our obscurity and take control of our own destiny.

By the mid-nineteenth century, several dedicated biologists were bent on discovering how heredity works. There was Charles Darwin (1809–1882) and his younger cousin Francis Galton (1822–1911); there was Carl von Nageli (1817–1891), a Swiss botanist who developed some idiosyncratic ideas about a hereditary material that he appropriately called the *idionplasm*; and there was a very clever German biologist, August Weismann (1834–1914) working in Freiburg. These were all well-educated university men with many students and assistants.

A further aspirant entered the field as a rank outsider, an obscure monk in an Augustinian monastery in the small cloth manufacturing town of Brünn about 120 kilometers north of Vienna. He had no university degrees and had no professional assistants to help him. It seemed no one was aware that he was working on the project until he presented his results in 1865—which everyone ignored. The 150th anniversary of Gregor Mendel's presentation of his theory of inheritance is celebrated in this book. He was unlike the wealthy gentlemen scientists of England and Europe, coming from quite a different social class. His parents were German-speaking peasant farmers at a tiny hamlet called Heinzendorf on the flat Silesian plains of Eastern Europe. The hamlet is about 20 miles from Brünn in the then Austrian-Hapsburg Empire. The parents had three children; a daughter Veronika, a middle son Johann (later changed to Gregor when entering the monastery), and the youngest daughter Theresia. Johann was born in 1822, and so was an exact contemporary of Francis Galton. He went to the local elementary school and because he seemed bright was sent to the local gymnasium—a secondary school to train students for the university. He ran short of money for living expenses around this time but his younger sister helped him out by giving Johann part of her share of the family farm—the part that was to have been her dowry.

If one were to lay bets on who would discover the solution to the heredity problem most people would choose Charles Darwin, an already world famous naturalist who had developed the theory of evolution by

means of natural selection. He had the time, patience, and resources to do any of the experiments that the other aspirants could do. He also had a very intelligent cousin, Francis Galton, who volunteered to help him.

My book will mainly focus on the most likely winners—the British scientists—and the most likely loser, the Catholic monk. This book starts with the relationship between Darwin and Galton. They both were searching for an answer to heredity because each had written a celebrated book, *The Origin of Species by Means of Natural Selection* (1859), and *Hereditary Genius* (1869), respectively. These books only made sense if the authors could give a satisfactory account of how bodily characteristics, such as mental abilities, were passed on from the parents to their offspring. This method of transmission of bodily features from generation to generation became the nub of the problem and eventually might show, according to Darwin, how new species might emerge.

Gregor Mendel worked in solitude on the inheritance of plant characteristics (such as seed color, petal color, height of plant) in the edible pea for 8 years without giving any clues as to his motivation. Perhaps he was studying nature (or reading the book of God), for no other worldly reasons than to fulfill his devotional duties because he was a monk (unusually also a priest) in an Augustinian monastery. No one knew he was working on this problem until presenting his results in 1865 to a scientific society in Brünn (now called Brno in the Czech Republic). His findings were published in 1866 and forty reprints were then available for Mendel to publicize his work to the scientific community. He almost certainly sent a copy to Darwin (why would he not?) since he possessed and had read a copy of Darwin's book in German translation on the *Origin of Species* that he had personally underlined in parts with pencil. His reprint showed that he had discovered a mechanism for the inheritance of plant features involving the transmission of discrete, countable particles. Features of the edible pea, such as pea color or shape, that seemed to be lost in one generation cropped up again a generation or two later in their original form that is skipping a generation. He also found a mathematical ratio recurring in his counts of the various inherited features. He had discovered a new constant in the form of a ratio of 1:3 that related to the inherited features of a plant. Discovery of such natural constants is always an important event. What did this ratio mean and where did it come from? What did it say about how these traits were inherited? Mendel created an algebraic model for inheritance that could explain how this ratio of 1:3 came about.

Mendel's particles (or elements) were eventually called genes from 1909 onward. His model turned out to be a correct solution on how heredity can work. By the age of 21 years Mendel had entered the monastery of St. Thomas in Brünn (now called Brno) and taken the vows of chastity, poverty, and obedience. He was ordained as a priest in 1847 at the age of 25. This means that there is very little social life to record, which

perhaps allowed him more time to concentrate on his scientific work. The final result of the *race* is announced in the Prologue—so we can stop reading and go home. No. Unlike sporting events, who wins and who loses is not the real issue. Finding a solution to an important scientific problem is never finished. The journey always goes on with fresh questions being raised by the preceding correct answers. And unlike sport, it is always more a cooperative than a competitive effort—even for a solitary scientist as Gregor Mendel. His results had to be confirmed by others before acknowledgment of how truly great his work was. This is what makes science such a fascinating field to pursue.

The definition of the word gene has varied from decade to decade as more information is discovered. Mendel called his discovery *Elemente*, in German, perhaps an element or factor in English. If a gene is defined as a *unit of heredity controlling a particular inherited characteristic of an organism* then Mendel discovered the gene. He had no idea what it was made of (we now know it is DNA), where it was to be found (on chromosomes in the nucleus), or how it worked (by making RNA), but he had built up a theoretical model that revealed some of its essential properties. The most talented scientists of the time in the British team (Darwin, Romanes, Galton, Huxley, Hooker, Pearson, and Weldon) did not appear to understand or act on Mendel's results and this book attempts to explain why. At least the British were one of the first to confirm Mendel's results in humans 34 years after Mendel had published. This gives some idea of the pace at which science often progresses.

Why the British team lost out arose partly from the different theories that Darwin and Mendel had conceived. Darwin and his assistants adopted and worked on a blending theory of inheritance in which multiple uncountable inherited particles, which Darwin called *gemmules*, are shed in varying numbers from every organ in the plant or animal for onward transmission to the progeny through the sex organs. Mendel adopted a binomial-type theory in which discrete particles (which he called *Elemente*, genes in modern parlance) are transmitted from parents to offspring in binomial proportions. Binomial here means an algebraic expression involving two terms, which Mendel called *Dominant* and *Recessive* (see [Chapter 13](#)). Mendel formulated the complex phenomenon of reproductive inheritance in algebra as a simple 1:3 ratio and this was and still is an astonishing feat of science.

Due to Darwin's great reputation and influence on others in the field he persuaded Francis Galton and other colleagues to work on his own theory until his death in 1882. Some of Galton's experiments got very close to Mendel's. However, even in Galton's publications he still published Darwin's blending theory, though he knew it was incorrect—an instance of how the progress of a project can be held up by the hero worship of a

famous senior colleague. Unfortunately, Galton and others kept doing the wrong experiments using Darwin's theory until Romanes' death in 1894.

There the matter stood until the early 1900s when three European botanists rediscovered that the results of Mendel's earlier experiments were correct. They all found numerical proportions of 1:3 in inherited plant characters after a variety of plant-breeding experiments. Meanwhile, a doctor, Archibald Garrod, at St. Bartholomew's Hospital (where I work) in London also found the same ratios in his studies of the inheritance of a number of rare diseases in first-cousin marriages. The stage was therefore set for a clash in theory between the Mendelians and Darwinians (sometimes called Biometricians) in 1904. The conclusions from all available evidence at the time favored the Mendelian interpretation, although some held to Darwin's blending theory for a few more years.

But to go back to the beginning when Charles Darwin was a 19-year-old medical student at Edinburgh University, when Johann (later changed to Gregor) Mendel was a small boy of 6 years helping his parents on their small farm on the flat plains of Silesia and always short of money, and Francis Galton, also 6-years old, was being spoiled by his wealthy parents in a grand house in the suburbs of Birmingham, United Kingdom.

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About the author

David J. Galton is an emeritus professor at London University from the Departments of Molecular Genetics and Metabolism, St. Bartholomew's Hospital. He gained doctorates in medicine (MD for work done at the National Institutes of Health, Bethesda, Maryland) and in science (DSc). He was elected to the Jephcott European Fellowship of the Royal Society of Medicine, London and to the Erasmus European Professorship. He has been the chairman of *Clinical Science*, HEART UK, secretary of the European Atherosclerosis Society, and vice president of the Galton Institute, London, among other administrative posts. He has published 8 books, written more than 400 research publications on genetics of human disease, and served on the editorial boards of the *European Journal of Clinical Investigation*, *Clinical Science*, and *Metabolism and Cardiovascular Disease*. He is elected Fellows of the Royal College of Physicians and of the Royal College of Ophthalmology London and has served as a consultant physician to St. Bartholomew's Hospital and Moorfields Eye Hospital, London, UK.

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chapter one

Seeds of hero worship

A Statue of a Hero with legs of iron, its feet part iron and part clay.

Daniel 2.34

It probably began as one of those intense emotional crushes that young boys sometimes feel for older cousins. It gradually developed into one of the worst cases of hero worship perhaps ever recorded. Even at the age of 64 years the hero worship burned as strongly, and Frank publicly confessed in a lecture that: *I rarely approached his general presence without an almost overwhelming sense of devotion and reverence, valuing his encouragement and approbation more perhaps than the whole world besides. This is the simple outline of my scientific history.*

Frank first met Charles at an impressionable age—Frank was just 6 years old, Charles, a medical student, was 19 when he came to visit the Galton family in Sparkbrook on the outskirts of Birmingham in 1828 (Figure 1.1). The Galton's estate owed their wealth to Frank's grandfather on his father's side who was something of an anomaly. He had amassed a large fortune in the manufacture and sale of arms for the Napoleonic wars of 1808–1814. He also professed to be a good Quaker promoting pacifism and the renunciation of war; he argued that what his customers did with his products was their affair and that guns might even deter conflict. This did not satisfy his colleagues and he was expelled from the Birmingham Society of Friends for *fabricating instruments for the destruction of mankind*. Frank's father, Samuel Tertius Galton, inherited a large part of his grandfather's wealth and had added to it by fulfilling the duties of a competent banker in Birmingham. He had founded a successful bank in Steelhouse Lane that enlarged their fortunes still further. He was happy in marriage to a joyful and unconventional young woman, Violetta Darwin, who was the daughter of Dr. Erasmus Darwin (1731–1802), a talented physician and a published poet of some distinction. Erasmus Darwin was the father of a well-to-do family doctor in Shrewsbury, Dr. Robert Darwin, whose son Charles was the cousin under whose spell Frank fell.

By 1827, the Galtons were living at the Larches, a fine country residence in the Sparkbrook district of suburban Birmingham. The name Larches came from two exceptionally tall larches that guarded either side of their driveway, and Francis (who was always called Frank by his

Figure 1.1 A portrait of Charles Darwin (1809–1882) by George Richmond in the 1830s.

family and close friends) was attracted ever after to this type of tree. The house was a handsome three-storied Georgian building with two ample side-wings, numerous outhouses, and paddocks at the rear end where his numerous brothers and sisters could ride their ponies. One of Frank's first memories in childhood was falling off his pony into a very muddy ditch and being dragged out his feet first by his eldest brother.

In that summer of 1828 when Frank first met Charles the Galton family was already large. Out of the 10 children, 7 had survived into late childhood. Frank had two elder brothers, and then came his four sisters. Frank was the baby of the family and excessively indulged by all his sisters, but especially by the third one, Adele—or Delly as Frank had called her from his early infancy. She greeted Frank's birth as a fairy gift and begged hard to be allowed to consider him as her sole charge. His other sisters petted him as the baby but Adele always had the greatest share of his heart. Frank's chief attractions as a child at that time were an imperfect articulation of English, an earnest desire of having his own way, many cunning tricks, and the source of a great deal of noise.¹ Charles Darwin's visit was really at the instigation of Frank's father who was worried about the educational prospects of his eldest son Erasmus named after his grandfather. Charles at 19 years was already enrolled as a medical student at Edinburgh University and the father's hope was that Charles's visit might inspire Frank's brother Erasmus to take up a similarly serious vocation. In reality, Charles appeared to spend more time with his insects than on his medical studies in Edinburgh.

They all used to take tea in the parlor, a high clean rather empty looking room at the back of the house. Frank's mother asked Charles if he wanted to go riding with them on the following day. No—he would really rather go out walking by himself in the fields at the back of their estate. Charles loved riding but he had recently contracted a passion for collecting insects, particularly beetles. What workmanship there is in the frame of beetles; such as living watches concealing the thousand springs and cogs of life. He pulled a pillbox out of his jacket pocket to show them and Frank was astonished by the appearance of the insect. It was about the size of a Brazil nut with a shining brown carapace, just like the shell of a conker. It had white wiggly stripes going down to a most ferocious looking proboscis. Here were two pincers looking like fret-saw blades facing each other, and two long antennae extended similar to curved pylons from the base. Woe betides any unsuspecting smaller insect that accidentally strayed between the blades of this ferocious beetle; they would be instantly mashed into little pieces. Charles referred to the beetle by a villainous sounding Latin name that Frank did not understand.

Frank was overwhelmed after tea when he followed Charles, at a distance, into the rear of their estate by the river.

It was a pleasant countryside at that time with gentle hills, the woods were full of fine timber, and the valleys beyond were comfortable and snug with rich meadows, and several neat farmhouses scattered here and there. Sadly the town of Birmingham has now encroached on all this farmland. Charles was scraping at the bark of a rotting old tree by the riverbank. Two rather dull colored beetles scampered out from a crevice and were immediately captured by Charles. One fell to the ground onto its back and its legs struggled similar to an orchestra playing Beethoven. The other, a gigantic black beetle tried to escape and Frank was thrilled to see Charles place the smaller of the beetles into his mouth to free his hand to capture the giant. A few seconds later, he spat it out. He told Frank and the others afterward that the beetle had spurted out an acrid juice from one of its body glands that tasted foul.

Charles loved collecting beetles and other insects. He might even have died for his love of them. While in South America exploring the province of Mendoza on the Beagle expedition he was attacked by the aggressive black assassin bug. This is a species of reduviid insect, the vinchuca bug that lives in the roofing and thatch of local houses. It was the most disgusting thing to feel the soft wingless insect about an inch long drop down from the roof and crawl over your body at night, quite fearlessly darting at any exposed skin surface to suck blood. Charles rather foolishly caught one the next day and placed it on a table, and although surrounded by people, the bold insect charged at his bare finger brandishing its sucker to draw blood. The wound caused no pain and it was curious to watch the insect's body during the attack change

from wafer thin to a globular one bloated with blood. This may be linked to Charles developing a long chronic illness in midlife that caused palpitations, shortness of breath, and he intermittently suffered stomach disorders for the rest of his life. At the age of 33 years, he had gone on a long tour of North Wales to study the geological effects of the extinct glaciers that formerly filled all the larger valleys. This was the last time that Charles ever felt strong enough to climb mountains or to take such long walks that these expeditions required, due to his shortness of breath and giddiness. No proper diagnosis was ever made. Charles went for various water cures with variable results, but the general conclusion was that his symptoms were due to some form of hypochondria.

The doctors might have misdiagnosed him, because by the beginning of the twentieth century, it was found that the reduviid bug transmits an infectious parasite that lodges in the heart and the lining of the intestines. The main features of this parasitic infection, Chagas disease, fit like a hand-in-glove to all the symptoms that Charles developed. A patient with Chagas disease often has a dilated heart with failure of the circulation producing breathlessness and fatigue; the intestines are affected leading to severe indigestion and abdominal distension; and to this day there is still no completely satisfactory treatment.

Of course, Frank copied Charles in his passion for collecting insects, but extended his collection to seashells, minerals, and coins. The beetles were his treasured possessions. A last will and testament was found in an old trunk that Frank wrote at the "advanced" age of 8 years, bequeathing his insect collection to his dearest sister Adele. He left his mineral and seashells to another sister Bessy.²

In the following days of Charles's visit, another incident occurred that had a big influence on Frank. His father had a scientific bent and as a banker had published a general paper on money supply, price level, and the exchange rate but without really clarifying the relationships that were involved. His great respect for science led him to collect all sorts of scientific instruments, although he probably could not tell you the difference between a theory, a hypothesis, or a concept and had no idea about the basic principles of scientific method. He collected objects such as antique telescopes, armillary spheres, and astrolabes, which were scattered around the house on shelves, taking the place of the usual domestic ornaments such as vases and porcelain figures. One highly prized instrument was an intricate eighteenth century vernier barometer housed in a beautiful inlaid wooden case. Charles wanted to examine it and Frank's father took it off the wall and very patiently tried to explain how it worked. Frank was hanging around in the background keeping close to his older cousin. Frank did not understand how atmospheric air could weigh anything or how it could depress a column of mercury. The brass vernier scale was also beyond him. But the whole episode awakened a sense

of mystery and delight in strange and exotic scientific instruments that remained with Frank ever after. As an adult Frank invented some instruments of his own and he tried to live his life by the scientific method. All aspects of his life were to be treated in the spirit of an experiment and to be measured, if possible. It provided a certain measure of detachment in his personal relationships. For example, if he approached an attractive woman at a social gathering, the encounter was treated as an experiment. How would it turn out? He remained as objective as any field observer and had no particular desire to see one outcome prevail over any other. He would just vary the conditions of approach at the next encounter to see if it would turn out differently. In the end, he invented an instrument to record the sexual attractiveness of all the women that he passed in the streets. He kept the instrument in his pocket and rated the women as they went by. He constructed a "beauty map" of the British Isles and found the least attractive women to be in Aberdeen; the most attractive were to be found in London.³

From Frank's father's point of view, Charles's visit was not particularly successful. Frank's brother Erasmus had nothing much in common with Charles. Indeed, they hardly spoke to each other during the whole stay. Erasmus was determined anyway to go into the Navy. However, the visit did succeed in influencing Frank; he wanted to copy what his cousin Charles was to do. Frank's mother was also keen for her son to study medicine because her father had been a very successful medical practitioner and she hoped to see the profession carried on in the family. So, from an early age it was always to be medical studies for Frank too.

Mendel's childhood was mainly spent on his father's farm where he helped to tend the orchards and became very interested in bee keeping, to make honey. His interest in bees survived to his time in the monastery where he looked after batches of hives to produce honey for the brethren. In childhood there is no record of him having had any scientific mentors.

*To be a doctor*⁴

It was Darwin's father who drove Charles to study medicine. *You care for nothing but shooting, dogs and rat-catching; and you will be a disgrace to yourself and all your family*, Charles was once told in a fit of irritation by his father. To avert this dire prognosis Charles was duly enrolled as a medical student at Edinburgh University. He only stayed in the course for 2 years. The subject was of intrinsic interest, but he found most of the lectures intolerably boring. There were long stupid lectures by a Professor Duncan on materia medica starting every morning at eight. They reminded Charles of the method used to detect excessive fluid that can accumulate in the abdomen by percussion of the stomach wall. The procedure is called listening for "shifting dullness," which perfectly fitted the contents

of the professor's lectures. Then a Professor Munro lectured on Anatomy. Charles disliked him and his lectures so much that he could not speak with decency about them. The Professor was dirty and slovenly in person as well as in his behavior. It was not uncommon for him to enter the lecture theatre bedaubed with blood from his recent dissections and his teaching was very out-of-date.

The final straw came when Charles had to attend an operation on a small child. The little girl had fallen under the wheel of a cart on Princes Street and she had crushed her right foot. The foot had become infected and then gangrene had set in and now needed to be amputated. There was no anesthesia in those days. The child was just wrapped in a blanket to stop her struggling with her foot protruding at the lower end. She was laid on a bare operating table with small wooden tables at its side on which was assortments of surgical instruments neatly laid out in rows. They resembled the sort of tools one might find in a carpenter's shop: large metal mallets, pincers, strong scissors, and ferocious looking hand-saws. One thick metallic saw had deep notches along its cutting edge to trap any bone or flesh from clogging the blade as it sawed through the leg. The surgeon, with his assistants dressed in loose fitting white tunics with rolled up sleeves held the child down, while the chief surgeon commenced the amputation. The eager faces of the students, including Charles, were ranged at the back of the room. Speed was of the essence; if the whole operation could be completed in 10–20 seconds she would have a good chance of survival. The death rate from amputations at this period was about 50 percent. The surgeon started to see into the leg about four inches below her right knee. The crescendo of screams of the little girl was unbearable, eventually subsiding into deep sobs of despair as the child became exhausted. She never lost consciousness throughout the whole operation of about four minutes, but toward the end her cries seemed to be disconnected from the activity of the surgeon—God alone knows what she was really suffering. This horrible and cruel experience was enough to drive Charles completely away from any more medical studies. The cruelty was unnecessary. His cousin, Frank, as a medical student also saw an emergency amputation of both legs of a powerful drayman who had fallen under the wheels of a stagecoach. The man was virtually dead drunk when he was brought into the operating theatre and the amputations were started immediately. He felt nothing, and indeed was in a drunken sleep throughout the whole procedure. One wonders why they could not make all preoperative patients "dead" drunk, so they were spared the pain of the surgery. Anesthesia was a marvelous invention but did not come into standard practice until the early 1840s with laughing gas (nitrous oxide), then in the mid-1840s with ether, and eventually in 1847 with chloroform.

Charles spent more and more time in Edinburgh studying his beloved insects and made some very interesting and original observations on the habits of marine invertebrates. He joined the local Plinian society to present some of his findings. He met there Robert Edmond Grant (1793–1874) who was an Edinburgh-trained physician. Grant had given up medicine to study the evolution of invertebrates and had even cited Erasmus Darwin's *Zoonomia* in his medical dissertation. During the Plinian Society's joint collecting trips to the sea shore, the older Grant introduced Darwin to the world of research and microscopic dissection—and this led to the Darwin's first scientific paper, delivered at the Plinian Society in 1827.

As Darwin later wrote in his autobiography, *He [Grant] one day, when we were walking together, burst forth in high admiration of Lamarck and his views on evolution. I listened in quiet astonishment, and as far as I can judge, without any effect on my mind.* Later in life, Darwin would distance himself from Grant, probably because of Grant's radical views on the transformation of species following on from Lamarck's ideas on the inheritance of acquired characters. Lamarck believed that if, for example, a father developed his musculature during his work as a blacksmith then his children would inherit as strong a musculature from him. Incidentally, Hippocrates antedated Lamarck's views on the inheritance of acquired characteristics by writing *characteristics thus acquired* (referring to the custom of molding the heads of newborn infants to an elongated from the spherical form) *at first by artificial means, but as time passes becomes an inherited characteristic so the practice... [of binding the head]... was no longer necessary.*

Darwin dropped out of medical studies altogether by 1828.

Frank's experiences studying medicine were quite different. He started at the Birmingham General Hospital in 1838 and rather enjoyed the charade of medicine. He particularly liked working in the dispensary. He became adept at making a variety of infusions, decoctions, and extracts of various herbs and minerals. He was never quite sure what good they did, so he started to try them on himself. He developed quite a taste for one particular decoction: a quart of *aqua vitae*, one ounce of aniseed bruised, one ounce of liquorice sliced, and half a pound of poppy seeds (from *Papaver somniferum*) all steeped for 10 days, after which the supernatant is poured off into a bottle containing two tablespoons of fine white sugar. It was meant to be a cure for asthma, but he found it quite a decent cordial after evening meals. He did worry afterward about how much opium was contained in the poppy seeds. He never felt any drowsy effects. He tried many of the drugs in the materia medica but croton oil stopped him dead in his tracks. Explosive vomiting and a cataract of watery diarrhea completely cured him of trying out any more of the other pharmaceutical preparations. More serious duties were gradually

imposed on him. He had to go with the surgeons on their morning ward rounds and then to attend the accident room. On the ward rounds he made notes of the cases and he wrote the prescribed treatment as dictated by the qualified doctors on a sheet of paper fixed to the head of the bed. He appreciated from the very first the importance of a careful study and record of every patient. He remembered one episode very clearly. A young girl was dying from typhus and he had been instructed to apply a mustard plaster. When he came to her she was fully conscious and she said in a faint but perfectly composed way: *Please leave me in peace. I know I am dying and am not suffering. There is nothing you can do for me.* He knew she was right and had not the heart to distress her any further.

In the accident room, his main duties were bandaging and plastering the victims of various accidents. Lacerations of the arms or legs needed tight bandaging to staunch the blood loss. Torn scalps from brawls were quite common at the weekends and his job was to shave the head and then to stitch the wounds together with a three-cornered "glove needle" that cuts its way through the skin. He also did cuppings and became quite good at tooth-drawing. He set broken limbs and occasionally had to reduce dislocations of the shoulder joints.

Why Frank thought medical practice contained a good deal of charlatanism came from his experiences with a Dr. M. who boasted of having no scientific acquirements and knowing next to nothing of anatomy or physiology. He always got his patients out of the hospital more quickly than his colleagues. His treatment was simple and invariable. It consisted of a strong purgative followed by a starvation diet and then subsequent over-feeding as soon as all fever had gone. The composition of his "drench" never varied whatever the illness he was treating. A big bottle was made of it every morning in the dispensary; it was so cheap that any surplus could be thrown away and a fresh infusion made for the next day.

After 2 years in Birmingham, Frank's father sent him to continue his studies at King's College London. Frank went to stay with four other students in the house of Professor Partridge. The professor lived near Charing Cross and was a brilliant man of about the age of 34. He was currently engaged in bringing out an encyclopedia of physiology, which was a remarkable project in those days. Frank enjoyed his studies with him and found the whole level of teaching at Kings College to be far superior to that of Birmingham. However, the chief attraction for him to come to London was that Charles had returned from his travels around South America and was living not far away in Upper Gower Street. He had worked up his travel journals for publication that eventually became known as *The Voyage of the Beagle*, and Frank frequently went to see the fossil animals that Charles had collected as well as to hear all about his journeys and adventures in South America. It was all too natural that Charles's passion for travel captivated Frank with the force of a migratory bird.

And he was able almost immediately to indulge this passion, as his father died prematurely leaving him with independent financial means so that he no longer needed to pursue his career in medicine.

Meanwhile, Mendel had completed his primary education at his local village school in Heinzendorf. Then his parents decided to send him to a nearby town (Troppau) to complete his secondary education at the local gymnasium—a type of secondary school to train students for the university. His father expected that Gregor would run the family farm and the education would prove invaluable for the rapidly changing agricultural practices of the time to improve crops and animals.

He graduated from the Gymnasium aged 19 with sufficient honors to gain entry to the Philosophical Institute in the nearby city of Olmutz to do the 2-year course required of gymnasium graduates before they could begin their university studies. This was a hard time for Mendel; he became homesick and depressed and was continually short of money for living expenses. He undertook private tutoring and his younger sister Theresia generously gave him a part of her share of the family farm—the part that was to have been her marriage settlement. This did not prevent her marrying a Jacob Schindler and she had three sons by him, Alois, Ferdinand, and Johann. Mendel had a life-long gratitude to his sister for her help and took a great interest in supporting his three nephews when they all lived in Brünn. Even so Mendel still could not make ends meet. At the suggestion of his physics teacher at the institute, Professor Friedrich Franz and Mendel, in common with many other penniless young men in search of an education, was advised to enter a monastery and to become a monk. Professor Franz, who was a priest himself, advised Mendel to go to the Augustinian monastery of St. Thomas in the city of Brünn. This was a wealthy industrial city about 120 km from Vienna mainly involved in the manufacture of clothing and other textiles. It was nicknamed the “Manchester” of the Austrian Hapsburg Empire. The population was about 70,000 and similar to some other cities in Austria there was a conflict between a Czech majority wanting to maintain their language and culture with a German minority in power prohibiting the use of Czech in many of the good schools. Brünn had an orchestra, a philosophical institute, and a new technical university. When Mendel arrived there was also an agricultural society founded by a group of amateur naturalists in the early 1800s and since 1827 its president was Cyrill Napp, Abbot of the Monastery in Brünn.

*To be an explorer*⁵

Charles Darwin made far better use of his travels than Francis Galton ever did. Darwin’s experience provided the inspiration for all his later work; it was the formative period of his life. Galton explored the darker regions

of Africa more for the love of adventure; he naively wanted to be an explorer similar to David Livingstone, and had pleasurable expectations of hunting big game. Galton gathered a few travelers' tales to tell about his explorations, whereas Darwin developed powerful and broad-ranging ideas from his expedition that challenged and changed the intellectual climate of England and the rest of the world.

Some of Darwin's ideas probably came from his grandfather, Erasmus Darwin, who had published a book in 1794 called *Zoonomia or the Laws of Organic Life*. In it, he stated his belief in the transformation of species from one type to another, and he believed that modification of species was brought about by the satisfaction of their internal drives as they adapted to their environmental conditions. Lamarck (1744–1829), the great French biologist, had published *Philosophie Zoologique* (1809) in which he stated that species grade into one another by a process of evolution (or transformation as he called it). Due to this modification of species during long periods of time the whole of the animal kingdom could be represented by a genealogy of branching lines such as a tree, the last branch being that of a man. He thought that some fossil animals had not become extinct but had been transformed into their now living descendents. Many other lesser known biologists had adopted and published their views on the evolution of species before the Beagle sets sail (Geoffroy Saint-Hilaire, W. Herbert, Professor Grant, and Herbert Spencer to name just a few); so animal evolution was very much "in the air." What Charles Darwin managed to find out was a plausible mechanism of how evolution might work by the process of natural selection.

As for exploration, Darwin had been fired by the popular travel books of Alexander von Humboldt (1769–1859). Von Humboldt was an explorer and naturalist, traveling widely in Central and South America between the years 1799 to 1804. He discovered a vast number of new plants and collected all the information on their habitats. He spent the years from 1804 to 1827 in Paris writing up the account of his expeditions. He was a pioneer in trying to relate the geography, geology, and climate of a locality to the plants and animals living there. He was among the first ecologists and Darwin was to develop a life-long interest in this subject.

After leaving Edinburgh failing to complete his medical studies Darwin was sent to Cambridge University with the intention of becoming a clergyman. There Darwin was invited to travel as an unpaid naturalist and geologist aboard a government ship, the Beagle, and was sent to explore and make a survey of the coast of South America. His father was dead set against the voyage but, with the help of his uncle Jos Wedgwood, Darwin managed to win his father's approval. They set sail from Plymouth on December 27, 1831 when Darwin was 22 (and Galton was 9 years old).

Her Majesty's ship, the Beagle, was a ten-gun brig under the command of Captain FitzRoy. The captain was a methodical and serious man taking 24 very good chronometers on board to calculate the exact longitude of Rio de Janeiro that was still unknown, and to chart the coastal waters around the rest of South America. The Panama Canal was still a plan on paper at the time and many shipwrecks occurred on the sea routes around Cape Horn. Darwin's job was more to chart nature's handiworks and he began by collecting specimens of the fauna and flora from each port of call. He collected an enormous number of animals, plants, and fossils. In Rio he was "red hot" for spiders; in Punta Alta for fossil bones; in Galapagos for finches and other birds.

He collected insects, especially because of his love for beetles, and also reptiles, marine animals, seashells, minerals, and plants from everywhere. He was indefatigable. The collections were all methodically labeled and sent back to England on homeward bound vessels. However, these were not mindless collections of samples by an amateur naturalist. Facts are not science—just as the dictionary is not literature. Darwin thought deeply and continuously about his collections, and over the years he developed two really revolutionary ideas—evolution by natural selection and the descent of man from animal progenitors.

While visiting the Galapagos Islands for 5 weeks in 1835, one problem forcibly struck him—that is the *mystery of mysteries, the first appearance of new beings on Earth*. Galapagos are a group of more than 19 separate volcanic islands situated astride the equator about 1000 km from the west coast of Ecuador. They had erupted from the sea bed in relatively recent times (that is about 5–9 million years ago); the formation of the main continental land masses of North and South America are about 500 million years old. When Galapagos emerged from the sea they had absolutely no life on them. How did they acquire the diversity of life that Darwin now encountered on the different islands? Perhaps, to start with, seeds drifted there on seaborne or windborne currents from South America and lodged on the islands to provide meager vegetation. Perhaps sea birds blown off course by gales arrived, settled, and started to spread more of the plant seeds after eating the fruits to other parts of the islands. The vegetation flourished on some of them and the original founder birds multiplied and diversified. Darwin observed that the birds always bore a striking resemblance to their nearest relatives on mainland America. There was no evidence for independent creation of a completely new species. However, there were some marked differences between the Galapagean birds and their closest relatives (or supposed ancestors) from mainland America. For example, the beaks of the finches on the separate islands were so different from each other that

the birds seem to have evolved into distinct species. An extract from his travel journals explains this:

Galapagos, The Voyage of the Beagle. Sept. 1835.

The remaining Island birds form a most singular group of finches, related to each other in the structure of their beaks, short tails, form of body and plumage: there are thirteen species, which Mr. Gould has divided into four sub-groups....the most curious fact is the perfect gradation in the size of their beaks in the different species, from one as large as a hawfinch to that of a chaffinch and even to that of a warbler. Seeing this gradation and diversity of structure in one small intimately related group of birds one might really fancy that from an original paucity of birds in this archipelago one species had been taken and modified for different ends.

The finch population on the islands did not appear to be a stable species. The advantages of the variation of beak sizes may not be immediately apparent, but it can give the individual bird a better chance of exploiting a different food supply. For example, a stronger beak will crack harder and larger seeds. The advantageous trait is passed on to their offspring and this can lead gradually to the formation of a new species, especially in isolated geographical areas such as the Galapagos where there are no mammalian predators (cats, dogs, stoats) to keep the original bird numbers down. Likewise a finer, thinner beak would be more suitable for capturing small insects crawling around the abundant cacti of the islands. Another finch had evolved woodpecker-like behavior and had flourished. No native woodpeckers had arrived from the American mainland in the past, so that this particular ecological niche was not filled. The finch was free to develop into a "woodpecker finch" and adapt to a food supply of insects and grubs found in tree barks. The bird had even learned to use a small twig or cactus needle in its beak to impale and extract small grubs from their holes in trees. Darwin concluded that possibly one species of finch had initially arrived on the islands and then had evolved into multiple new species. This idea was of course heretical. The account in genesis revealed that God individually created all the different species found on our planet within a week.

Darwin's second idea was even more heretical concerning his suspicions about the origin of humans. While visiting Tierra del Fuego, he was astonished to see men and women living in such an abject and savage state. They certainly did not appear to be made in God's image.

Tierra del Fuego, Voyage of the Beagle Dec 1832.

These poor wretches were stunted in their growth, their hideous faces bedaubed with white paint, their skins filthy and greasy, their hair entangled, their voices discordant and their gestures violent. Viewing such men one can hardly make oneself believe that they are fellow-creatures and inhabitants of the same world.... I shall never forget how wild and savage one group appeared: suddenly four or five men came to the edge of an overhanging cliff; they were absolutely naked and their long hair streamed about their faces; they held rugged staffs in their hands and, springing from the ground they waved their arms round their heads and sent forth the most hideous yells.

Later, Darwin wrote with some persuasion that such savages might indeed be our progenitors; that we had evolved from species similar to them after much social development and modification, rather than having descended from Adam and Eve out of the Garden of Eden.

Galton admired Darwin's travel journal immensely. The intellectual energy of the man and his passion for collecting left Galton completely enthralled. Darwin's revolutionary theories were expressed with meticulous care and close reasoning in his two most influential books on the *Origin of Species by means of Natural Selection* (1859) and the *Descent of Man* (1871). His travel book, the *Voyage of the Beagle* (1839), was a best seller and ran to 20 editions. It has remained in print to this day.

Galton also published an account of his travels in South Africa but it is almost embarrassing to write about them in the same manner as Darwin's. The only ideas stimulating Galton were the thought of hunting big game, exploring, and opening up new tracts of the dark continent. In the 1850s, there were vast blank spaces on the map of Africa and his goal was to explore the country between the West Coast and a newly discovered lake, Lake Ngami, in what is now Namibia.

Galton left England on April 5, 1850 in an old teak-built East Indiaman called the *Dalhousie*. She was very slow and quite incapable of beating into a head wind. It took them nearly 80 days to reach Cape Town. Galton was no naturalist, but he was lucky to secure the services of Charles Andersson, a young Swede, who spoke English fluently and he became Galton's traveling companion. Galton's published account of the expedition is full of lively anecdotes with a smattering of anthropology. Galton was more interested in the social habits of the tribal people he encountered than the fauna and flora of the land.

The Ovampos tribes were the most interesting of the several groups of the inhabitants that they encountered. Unlike the neighboring tribe, the Damaras, they were kept under very strict discipline by the chief. Galton was not free to do what he liked in their company but had to depend on their wishes. Chief Nangoro was supreme. Galton could not enter the territory, or trade in it, or leave without the chief's permission. Galton tried very hard to make himself agreeable to Chief Nangoro. Before leaving London he had purchased a quantity of beads, trinkets, and other ornaments as gifts of passage for such tribes. In Drury Lane, he had bought a magnificent tinsel crown, a theatrical prop, made out of strong cardboard. On first being introduced to the chief, Galton gravely offered him the crown. The chief bowed his head with dignity on which Galton placed the crown. His head was rather like a bullock's, so Galton patted the crown down with great solemnity to make it sit tight. He looked every inch a king. The chief's entourage went into cheers of delight and Nangoro himself gave every sign of self-satisfaction after seeing his reflection in the mirror that Galton carried with him. However, Galton had to pay for this elaborate ceremony. On returning to his tent in the evening he found a fine-looking buxom negress called Chipanga wearing a great quantity of beads and rings but very little else cavorting around his tent humming sentimental airs to herself. She had a decidedly nice-looking face, very open and merry, but with rather coarse features. Galton was expected to take her as a temporary wife. Her body was covered with red ochre and smeared with butter fat and as capable of leaving a mark on anything she touched as a well-inked printer's roller. Galton was dressed in his last well-preserved safari suit made of white linen, so he had her removed from the tent with scant ceremony. He wrote in his travel book that:

This is one of the drawbacks of becoming too friendly with an African Chief. They expect you to receive a spare wife or niece in marriage and take great umbrage if you refuse.

The Ovampos were mainly agricultural people who sometimes employed (or enslaved) Hottentots to help with their animal husbandry. One day Galton encountered a perfect Venus among Hottentot women, and was aghast at the enormous size of her bottom. He had never seen a back-end project so far out. He always professed to be a scientific man and was exceedingly anxious to obtain accurate measurements of her backside; but there was difficulty in doing this. He spoke no word of Hottentot and could never explain to the lady what the object of his foot rule could be if laid across her bottom. He therefore felt in a dilemma as he gazed at her behind, a gift of bounteous nature to this native tribe, which no Mantua worker with all her crinoline and stuffing can do otherwise than humbly imitate. The object of his admiration stood under a tree and was turning

her bottom about to all points of the compass as ladies who wish to be admired often do. Of a sudden his eyes fell on his sextant; a bright thought struck him and he took a series of observations on her figure in every direction, up and down, crossways, diagonally, and so forth, and he registered them carefully on an outline drawing for fear of any mistakes. This being done he boldly pulled out his measuring tape and recorded the distance from where he was to the place where she stood. Having thus obtained both bases and angles it was a simple matter to work out the degree of the callipygian (what a beautiful bottom) by trigonometry and logarithms.

Trivialities such as these show the difference between the travels of Darwin and Galton. Galton's book was not a best seller but did run to a third edition. Extracts from a letter of Darwin summed up what he thought of Galton's exploits.

Sea houses, Eastbourne, Sussex⁶ July 1853.

...Last night I finished your volume with such lively interest that I cannot resist the temptation of expressing my admiration at your expedition and at the capital account you have published of it. What labours and dangers you have gone through; I can hardly fancy how you can have survived them, for you did not formerly look very strong, but you must be as tough as one of your own African wagons!

I live at a village called Downe near Farnborough in Kent and employ myself in Zoology, but the objects of my study are very small fry and to a man accustomed to rhinoceroses and lions, would appear infinitely insignificant.

I should very like to hear something about your brothers: I very distinctly remember the pleasant visit at the Larches and having many rides with them on ponies without stirrups.

We have come to Eastbourne for a few weeks for sea bathing with all our children, now numbering seven.

This letter brings up the topic of their family lives, which turned out to be very different for each of them. Darwin did most of his best work in his family home surrounded by his wife and numerous children. Galton's marriage was childless and he seemed to have spent as much time away from home as possible attending scientific meetings and traveling the world.

Mendel had no such advantages of exploring the world and learning from it. His travels were mainly around the local towns of Silesia, a rather barren corner of the Austrian-Hungarian Empire. He first went abroad at the age of 40 years to visit and to help set up a display stand on crystallization at a technological exhibition in London in 1862.