LITTLE MASTER PIECES

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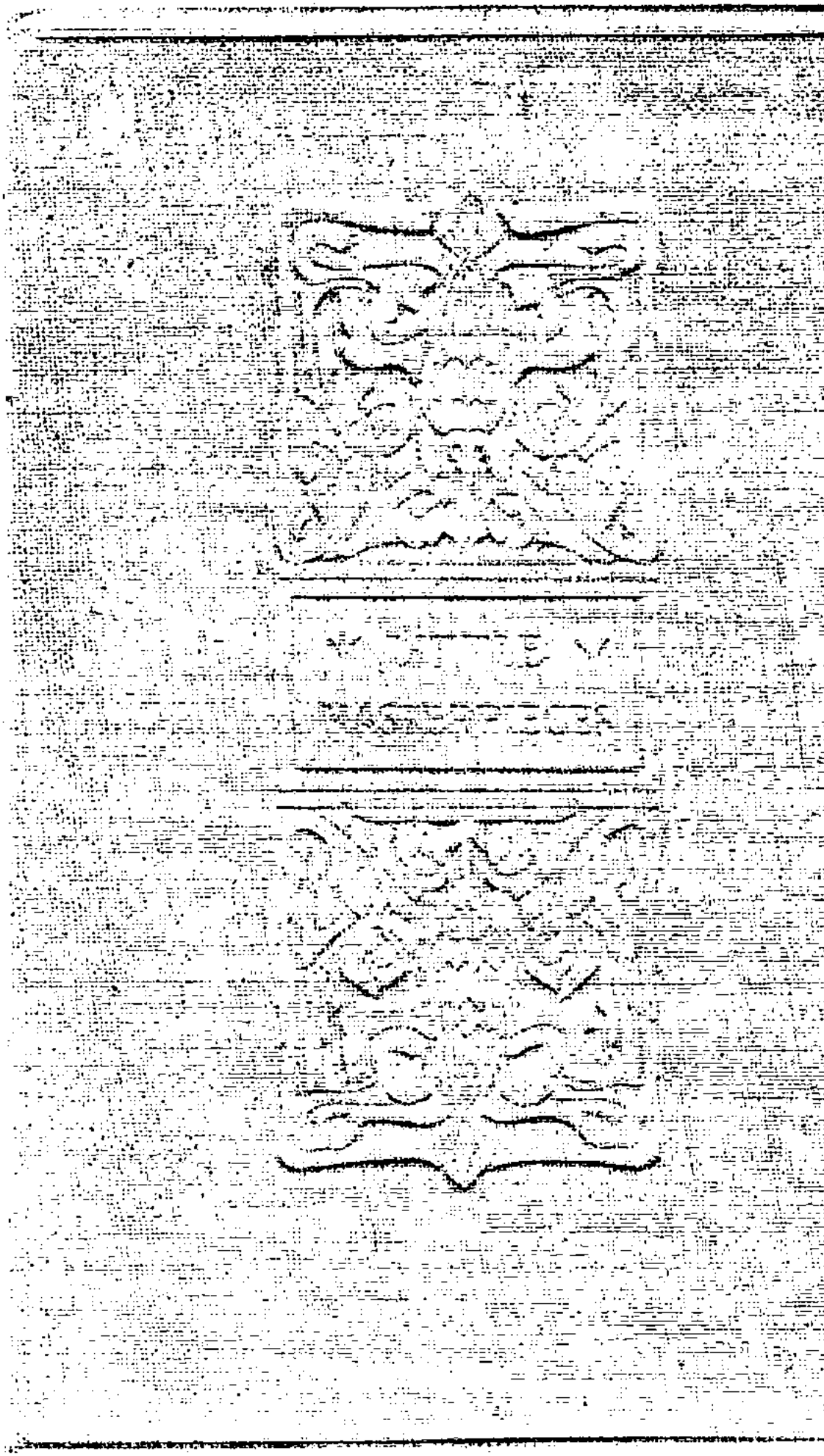

Library of
Little Masterpieces

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Little Masterpieces

In Forty-four Volumes

AUTOBIOGRAPHY

Edited by

GEORGE ILES

VOLUME XXXIII

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PREFACE

IN THE opening pages of this book Darwin, the greatest naturalist of all time, tells us how he was educated, and how he did his work. He lays stress on what he learned on the long voyage of the *Beagle*, but there were clearly uncommon natural gifts in the young observer who, day by day, jotted down his famous "Researches." Huxley, with less original genius than Darwin, had more expository power, and a genuine love of a fight. And no wonder, for usually the victory was his. By dint of perseverance he became a capital speaker and lecturer. Then, by virtue of unsparing self-discipline, he learned to write with all the ease and pith of his platform utterances. Passing from natural history to astronomy, we next listen to Professor Newcomb, the ablest living student of the heavens. It is worth while to compare his education, chiefly at the hands of his father, a country schoolmaster, with the elaborate training which fell to the lot of Darwin and Huxley. The comparison may confirm the view maintained by Francis Galton, a cousin of Darwin, that nature and not nurture is the chief factor in making a man great.

Professor Newcomb, and his brethren in astronomy, are content to regard the earth as

an oblate spheroid, of such-and-such form, dimensions, and motions, very useful as the standing-ground for telescopes. A geologist confining his thought and work to this same planet, finds its story every whit as fascinating as that of the firmament itself. He discovers continuous development to be as true of the strata and fossils beneath his feet as it is of the uncounted orbs in the sky. Sir Archibald Geikie, the chief living geologist, tells us how he came to choose his career through a visit to neighbouring stone-quarries while a schoolboy. His recital has golden hints for other schoolboys, and for their teachers, too.

We now pass from men of research to men of ingenuity, to great inventors, first hearing what James Nasmyth, the devisor of the steam hammer, owed to the lessons of his father, an artist. Art, too, had much influence in the home training and early work of Sir Henry Bessemer. In the great tasks of his life he was under an immeasurable debt to the dexterity first elicited and trained as he reproduced medals and medallions with admirable fidelity. While Bessemer revolutionised the practice of engineering by employing Fire in a new way, Edison has won his triumphs in harnessing Electricity for new services of the first importance. His account of the early days of his incandescent lamp, as here given, is but one leaf from the history of his achievements. While at work on that lamp, one of Edison's assistants was

Edward Goodrich Acheson, who then began researches in carbon which have won him fame and fortune. He tells us here how he came to produce carborundum, second only to the diamond in hardness, and artificial graphite, a much better electrical conductor than the natural variety. In 1895 a new era dawned for electrical research as Professor Röntgen discovered the X-rays, which easily take their way through substances opaque to common light. Radio-activity, thus manifest, is displayed by radium in ways so remarkable as to recast the traditional ideas of physics and chemistry. M. Pierre Curie who, with his wife, discovered radium, tells its amazing properties in an interview with Mr. Cleveland Moffett.

As a master of the science of business Andrew Carnegie is a representative figure. It was in discerning the value of a new mechanical invention that, as he here tells us, he laid the foundation of his fortune. He owes much to technical science, and magnificently has he repaid the debt. His gifts, too, have always carried with them the sagacity, the coöperation with wise counsellors, which as a chieftain of industry have brought him his colossal gains.

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MEN OF SCIENCE

CHARLES DARWIN

[Charles Darwin, who more than any other thinker established the theory of evolution, was a man who did honor to human nature. He was not only honest and truthful, he was scrupulous in a high-minded way. He was sympathetic and courageous, generous and just. His goodness was of the rare kind that is lovable. Through many years of ill health he prosecuted his tasks with a persistence seldom displayed by students in full vigor of body. His character shines out in his Autobiography, laid under contribution in the pages which follow. It was written in his fifty-ninth year, and forms part of the first volume of his "Life and Letters" edited by his son, Francis Darwin. In succession to that work "More Letters of Charles Darwin" were published in two volumes in 1905. These books, and all the works of Charles Darwin, are published by D. Appleton & Co., New York.

Darwin's discovery of the law of natural selection was made public in 1858. That law, strange to say, was independently discovered by Alfred Russel Wallace. Both naturalists presented their outlines of the theory at the same meeting of the Linnæan Society of London. In 1870, in his book on "Natural Selection" Wallace said: "I have felt all my life the most sincere satisfaction that Mr. Darwin had been at work long before me, and that it was not left for me to attempt to write "The Origin of Species." I have long since measured my own strength, and know well that it would be quite unequal to that task. Far abler men than myself may confess, that they have not that untiring patience in accumulating, and that wonderful skill in using, large masses of facts of the most varied kind . . . that wide and accurate physiological knowledge, that acuteness in devising and carrying out experiments — and that admirable style of composition, at once clear, persuasive and judicial — qualities which in their harmonious combination mark out

Mr. Darwin as the man, perhaps of all men now living, best fitted for the great work he has undertaken and accomplished."]

As a Child

I was born at Shrewsbury on February 12, 1809, and my earliest recollection goes back only to when I was a few months over four years old, when we went to near Abergele, in Wales, for sea-bathing, and I recollect some events and places there with some little distinctness.

My mother died in July, 1817, when I was a little over eight years old, and it is odd that I can remember hardly anything about her except her death-bed, her black velvet gown, and her curiously constructed work-table. In the spring of this same year I was sent to a day-school in Shrewsbury, where I stayed a year. I have been told that I was much slower in learning than my younger sister Catherine, and I believe that I was in many ways a naughty boy.

By the time I went to this day-school my taste for natural history, and more especially for collecting, was well developed. I tried to make out the names of plants, and collected all sorts of things, shells, seals, franks, coins, and minerals. The passion for collecting which leads a man to be a systematic naturalist, a virtuoso, or a miser, was very strong in me, and was clearly innate, as none of my sisters or brother ever had this taste.

One little event during this year has fixed itself very firmly in my mind, and I hope that it has done so from my conscience having been afterward sorely troubled by it; it is curious as showing that apparently I was interested at this early age in the variability of plants. I told another little boy (I believe it was Leighton, who afterward became a well-known lichenologist and botanist), that I could produce variously coloured polyanthuses and primroses by watering them with certain coloured fluids, which was of course a monstrous fable, and had never been tried by me. I may here also confess that as a little boy I was much given to inventing deliberate falsehoods, and this was always done for the sake of causing excitement. For instance, I once gathered much valuable fruit from my father's trees and hid it in the shrubbery, and then ran in breathless haste to spread the news that I had discovered a hoard of stolen fruit.

As a Schoolboy

In the summer of 1818 I went to Dr. Butler's great school in Shrewsbury, and remained there for seven years till mid-summer 1825, when I was sixteen years old. I boarded at this school, so that I had the great advantage of living the life of a true schoolboy; but as the distance was hardly more than a mile to my home, I very often ran there in the longer intervals between the callings over and before locking up at night. This, I think, was in many ways

advantageous to me by keeping up home affections and interests. I remember in the early part of my school life that I often had to run very quickly to be in time, and from being a fleet runner was generally successful; but when in doubt I prayed earnestly to God to help me, and I well remember that I attributed my success to the prayers and not to my quick running, and marvelled how generally I was aided.

I have heard my father and elder sister say that I had, as a very young boy, a strong taste for long solitary walks; but what I thought about I know not. I often became quite absorbed, and once, whilst returning to school on the summit of the old fortifications round Shrewsbury, which had been converted into a public foot path with no parapet on one side, I walked off and fell to the ground, but the height was only seven or eight feet. Nevertheless the number of thoughts which passed through my mind during this very short, but sudden and wholly unexpected fall, was astonishing, and seem hardly compatible with what physiologists have, I believe, proved about each thought requiring quite an appreciable amount of time.

Nothing could have been worse for the development of my mind than Dr. Butler's school, as it was strictly classical, nothing else being taught, except a little ancient geography and history. The school as a means of education

to me was simply a blank. During my whole life I have been singularly incapable of mastering any language. Especial attention was paid to verse-making, and this I could never do well. I had many friends, and got together a good collection of old verses, which by patching together, sometimes aided by other boys, I could work into any subject. Much attention was paid to learning by heart the lessons of the previous day; this I could effect with great facility, learning forty or fifty lines of Virgil or Homer whilst I was in morning chapel; but this exercise was utterly useless, for every verse was forgotten in forty-eight hours. I was not idle, and with the exception of versification, generally worked conscientiously at my classics, not using cribs. The sole pleasure I ever received from such studies was from some of the odes of Horace, which I admired greatly.

When I left the school I was for my age neither high nor low in it; and I believe that I was considered by all my masters and by my father as a very ordinary boy, rather below the common standard in intellect. To my deep mortification my father once said to me, "You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family." But my father, who was the kindest man I ever knew and whose memory I love with all my heart, must have been angry and somewhat unjust when he used such words.

Looking back as well as I can at my character

during my school life, the only qualities which at this period promised well for the future were, that I had strong and diversified tastes, much zeal for whatever interested me, and a keen pleasure in understanding any complex subject or thing. I was taught Euclid by a private tutor, and I distinctly remember the intense satisfaction which the clear geometrical proofs gave me. I remember, with equal distinctness, the delight which my uncle gave me (the father of Francis Galton) by explaining the principle of the vernier of a barometer. With respect to diversified tastes, independently of science, I was fond of reading various books, and I used to sit for hours reading the historical plays of Shakespeare, generally in an old window in the thick walls of the school. I read also other poetry, such as Thomson's "Seasons," and the recently published poems of Byron and Scott. I mention this because later in life I wholly lost, to my great regret, all pleasure from poetry of any kind, including Shakespeare. In connection with pleasure from poetry, I may add that in 1822 a vivid delight in scenery was first awakened in my mind, during a riding tour on the borders of Wales, and this has lasted longer than any other æsthetic pleasure.

Early in my school days a boy had a copy of the "Wonders of the World," which I often read, and disputed with other boys about the veracity of some of the statements; and I believe that this book first gave me a wish to

travel in remote countries, which was ultimately fulfilled by the voyage of the *Beagle*.

At Edinburgh University

Toward the close of my school life my brother worked hard at chemistry, and made a fair laboratory with proper apparatus in the tool-house in the garden, and I was allowed to aid him as a servant in most of his experiments. He made all the gases and many compounds, and I read with great care several books on chemistry, such as Henry and Parkes's "Chemical Catechism." The subject interested me greatly and we often used to go on working till rather late at night. This was the best part of my education at school, for it showed me practically the meaning of experimental science. The fact that we worked at chemistry somehow got known at school, and as it was an unprecedented fact, I was nicknamed "Gas." I was also once publicly rebuked by the head-master, Dr. Butler, for thus wasting my time on such useless subjects; and he called me very unjustly a trifler, and it seemed to me a fearful reproach.

As I was doing no good at school, my father wisely took me away at a rather earlier age than usual, and sent me (October, 1825) to Edinburgh University with my brother, where I stayed for two years or sessions. My brother was completing his medical studies, though I do not believe he ever really intended to practise,

and I was sent there to commence them. But soon after this period I became convinced from various small circumstances that my father would leave me property enough to subsist on with some comfort, though I never imagined that I should be so rich a man as I am; but my belief was sufficient to check any strenuous efforts to learn medicine.

The instruction at Edinburgh was altogether by lectures, and these were intolerably dull, with the exception of those on chemistry by Hope; but to my mind there are no advantages and many disadvantages in lectures compared with reading. Dr. Duncan's lectures on Materia Medica at eight o'clock on a winter's morning are something fearful to remember. Dr. —— made his lectures on human anatomy as dull as he was himself, and the subject disgusted me. It has proved one of the greatest evils in my life that I was not urged to practise dissection, for I should soon have got over my disgust; and the practice would have been invaluable for all my future work. This has been an irremediable evil, as well as my incapacity to draw. I also attended regularly the clinical wards in the hospital. Some of the cases distressed me a good deal, and I still have vivid pictures before me of some of them; but I was not so foolish as to allow this to lessen my attendance. I cannot understand why this part of my medical course did not interest me in a greater degree; for during the summer before

coming to Edinburgh I began attending some of the poor people, chiefly children and women in Shrewsbury; I wrote down as full an account as I could of the cases with all the symptoms, and read them aloud to my father, who suggested further inquiries and advised me what medicines to give, which I made up myself. At one time I had at least a dozen patients, and I felt a keen interest in the work. My father, who was by far the best judge of character whom I ever knew, declared that I should make a successful physician — meaning by this one who would get many patients. He maintained that the chief element of success was exciting confidence; but what he saw in me which convinced him that I should create confidence I know not. I also attended on two occasions the operating theatre in the hospital at Edinburgh, and saw two very bad operations, one on a child, but I rushed away before they were completed. Nor did I ever attend again, for hardly any inducement would have been strong enough to make me do so; this being long before the blessed days of chloroform. The two cases fairly haunted me for many a long year.

My brother stayed only one year at the University, so that during the second year I was left to my own resources; and this was an advantage, for I became well acquainted with several young men fond of natural science. One of these was Ainsworth, who afterward published his

travels in Assyria; he was a Wernerian geologist, and knew a little about many subjects. Dr. Coldstream was a very different young man, prim, formal, highly religious, and most kind-hearted; he afterward published some good zoölogical articles. A third young man was Hardie, who would, I think, have made a good botanist, but died early in India. Lastly, Dr. Grant, my senior by several years, but how I became acquainted with him I cannot remember; he published some first-rate zoölogical papers, but after coming to London as professor in University College, he did nothing more in science, a fact which has always been inexplicable to me. I knew him well; he was dry and formal in manner, with much enthusiasm beneath this outer crust. He one day, when we were walking together, burst forth in high admiration of Lamarck and his views on evolution. I listened in silent astonishment, and as far as I can judge without any effect on my mind. I had previously read the "Zoönomia" of my grandfather, Erasmus Darwin; in which similar views are maintained, but without producing any effect on me. Nevertheless, it is probable that the hearing rather early in life such views maintained and praised may have favoured my upholding them under a different form in my "Origin of Species." At this time I admired greatly the "Zoönomia"; but on reading it a second time after an interval of ten or fifteen years, I was much disappointed; the propor-

tion of speculation being so large to the facts given.

At Cambridge University

[After two sessions at Edinburgh University, Darwin proceeded to Cambridge.]

During the three years which I spent at Cambridge my time was wasted, as far as the academical studies were concerned, as completely as at Edinburgh and at school. I attempted mathematics, and even went during the summer of 1828 with a private tutor (a very dull man) to Barmouth, but I got on very slowly. The work was repugnant to me, chiefly from my not being able to see any meaning in the early steps in algebra. This impatience was very foolish, and in after years I have deeply regretted that I did not proceed far enough at least to understand something of the great leading principles of mathematics, for men thus endowed seem to have an extra sense. But I do not believe that I should ever have succeeded beyond a very low grade. With respect to Classics I did nothing except attend a few compulsory college lectures, and the attendance was almost nominal. In my second year I had to work for a month or two to pass the preliminary examination, which I did easily. Again, in my last year I worked with some earnestness for my final degree of B. A., and brushed up my Classics, together with a little Algebra and Euclid, which latter gave me much pleasure,

as it did at school. In order to pass the B. A examination, it was also necessary to get up Paley's "Evidences of Christianity," and his "Moral Philosophy." This was done in a thorough manner, and I am convinced that I could have written out the whole of the "Evidences" with perfect correctness, but not of course in the clear language of Paley. The logic of this book and, as I may add, of this "Natural Theology," gave me as much delight as did Euclid. The careful study of these works, without attempting to learn any part by rote, was the only part of the academical course which, as I then felt and as I still believe, was of the least use to me in the education of my mind. I did not at that time trouble myself about Paley's premises; and taking these on trust, I was charmed and convinced by the long line of argumentation. By answering well the examination questions in Paley, by doing Euclid well, and by not failing miserably in Classics, I gained a good place among the crowd of men who do not go in for honours. Oddly enough, I cannot remember how high I stood, and my memory fluctuates between the fifth, tenth, or twelfth name on the list. (He was tenth.)

Public lectures on several branches were given in the University, attendance being quite voluntary; but I was so sickened with lectures at Edinburgh that I did not even attend Sedgwick's eloquent and interesting lectures. Had I done so I should probably have become a

geologist earlier than I did. I attended, however, Henslow's lectures on Botany, and liked them much for their extreme clearness, and the admirable illustrations; but I did not study botany. Henslow used to take his pupils, including several of the older members of the University, field excursions, on foot or in coaches, to distant places, or in a barge down the river, and lectured on the rarer plants and animals which were observed. These excursions were delightful.

As a Collector

But no pursuit at Cambridge was followed with nearly so much eagerness or gave me so much pleasure as collecting beetles. It was the mere passion for collecting, for I did not dissect them, and rarely compared their external characters with published descriptions, but got them named anyhow. I will give a proof of my zeal: One day, on tearing off some old bark, I saw two rare beetles, and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one which I held in my right hand into my mouth. Alas! it ejected some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost, as was the third one.

I was very successful in collecting, and invented two new methods. I employed a labourer to scrape, during the winter, moss off the old trees

and place it in a large bag, and likewise to collect the rubbish at the bottom of the barges in which reeds are brought from the fens, and thus I got some very rare species. No poet ever felt more delighted at seeing his first poem published than I did at seeing, in Stephens's "Illustrations of British Insects," the magic words, "captured by C. Darwin, Esq." I was introduced to entomology by my second cousin, W. Darwin Fox, a clever and most pleasant man, who was then at Christ's College, and with whom I became extremely intimate. Afterward I became well acquainted, and went out collecting, with Albert Way of Trinity, who in after years became a well-known archæologist; also with H. Thompson of the same college, afterwards a leading agriculturist, chairman of a great railway, and Member of Parliament. It seems therefore that a taste for collecting beetles is some indication of future success in life!

Voyage of the "Beagle" From December 27, 1831, to October 2, 1836

On returning home in the summer of 1831, from a short geological tour in North Wales, I found a letter from Henslow [Professor of Botany at Cambridge], informing me that Captain Fitz-Roy was willing to give up part of his own cabin to any young man who would volunteer to go with him without pay as naturalist to the voyage of the *Beagle*. I have given, as I believe, in my MS. Journal an account of

all the circumstances which then occurred; I will here only say that I was instantly eager to accept the offer, but my father strongly objected, adding the words, fortunate for me, "If you can find any man of common sense who advises you to go I will give my consent." So I wrote that evening and refused the offer. On the next morning I went to Maer to be ready for September 1st, and, whilst out shooting, my uncle, Josiah Wedgwood, sent for me, offering to drive me over to Shrewsbury and talk with my father, as my uncle thought it would be wise in me to accept the offer. My father always maintained that he was one of the most sensible men in the world, and he at once consented in the kindest manner. I had been rather extravagant at Cambridge, and to console my father, said, "that I should be deuced clever to spend more than my allowance whilst on board the *Beagle;*" but he answered with a smile, "But they tell me you are very clever."

Next day I started for Cambridge to see Henslow, and thence to London to see Fitz-Roy, and all was soon arranged. Afterward, on becoming very intimate with Fitz-Roy, I heard that I had run a very narrow risk of being rejected, on account of the shape of my nose! He was an ardent disciple of Lavater, and was convinced that he could judge of a man's character by the outline of his features; and he doubted whether any one with my nose could possess sufficient energy and determination

for the voyage. But I think he was afterward well satisfied that my nose had spoken falsely.

The voyage of the *Beagle* has been by far the most important event in my life, and has determined my whole career; yet it depended on so small a circumstance as my uncle offering to drive me thirty miles to Shrewsbury, which few uncles would have done, and on such a trifle as the shape of my nose. I have always felt that I owe to the voyage the first real training or education of my mind; I was led to attend closely to several branches of natural history, and thus my powers of observation were improved, though they were always fairly developed.

The investigation of the geology of all the places visited was far more important, as reasoning here comes into play. On first examining a new district nothing can appear more hopeless than the chaos of rocks; but by recording the stratification and nature of the rocks and fossils at many points, always reasoning and predicting what will be found elsewhere, light soon begins to dawn on the district, and the structure of the whole becomes more or less intelligible. I had brought with me the first volume of Lyell's "Principles of Geology," which I studied attentively; and the book was of the highest service to me in many ways. The very first place which I examined, namely St. Jago in the Cape de Verde Islands, showed me clearly the wonderful superiority of Lyell's manner of

treating geology, compared with that of any other author whose works I had with me or ever afterward read.

Another of my occupations was collecting animals of all classes, briefly describing and roughly dissecting many of the marine ones; but from not being able to draw, and from not having sufficient anatomical knowledge, a great pile of MS. which I made during the voyage has proved almost useless. I thus lost much time, with the exception of that spent in acquiring some knowledge of the Crustaceans, as this was of service when in after years I undertook a monograph of the Cirripedia [Barnacles].

During some part of the day I wrote my Journal of Researches, and took much pains in describing carefully and vividly all that I had seen; and this was good practice. My journal served also, in part, as letters to my home, and portions were sent to England whenever there was an opportunity.

The above various special studies were, however, of no importance compared with the habit of energetic industry and of concentrated attention to whatever I was engaged in, which I then acquired. Everything about which I thought or read was made to bear directly on what I had seen or was likely to see; and this habit of mind was continued during the five years of the voyage. I feel sure that it was this training which has enabled me to do whatever I have done in science.

Looking backward, I can now perceive how my love for science gradually preponderated over every other taste. During the first two years my old passion for shooting survived in nearly full force, and I shot myself all the birds and animals for my collection; but gradually I gave up my gun more and more, and finally altogether, to my servant, as shooting interfered with my work, more especially with making out the geological structure of a country. I discovered, though unconsciously and insensibly, that the pleasure of observing and reasoning was a much higher one than that of skill and sport. That my mind became developed through my pursuits during the voyage is rendered probable by a remark made by my father, who was the most acute observer whom I ever saw, of a sceptical disposition, and far from being a believer in phrenology; for on first seeing me after the voyage, he turned round to my sisters, and exclaimed, "Why, the shape of his head is quite altered."

First Books

In the early part of 1844 my observations on the volcanic islands visited during the voyage of the *Beagle* were published. In 1845 I took much pains in correcting a new edition of my "Journal of Researches" in the natural history and geology of the countries visited by the *Beagle*, which was originally published in 1839 as part of Fitz-Roy's work. The success of

this, my first literary child, always tickles my vanity more than that of any of my other books. Even to this day it sells steadily in England and the United States, and has been translated for the second time into German, and into French and other languages. This success of a book of travels, especially of a scientific one, so many years after its first publication, is surprising. Ten thousand copies have been sold in England of the second edition. In 1846 my "Geological Observations on South America" were published. I record in a little diary, which I have always kept, that my three geological books ("Coral Reefs" included) consumed four and a half years' steady work; "and now it is ten years since my return to England. How much time have I lost by illness!" I have nothing to say about these three books except that to my surprise new editions have lately been called for.

Later Books

[In November, 1859, Darwin's "Origin of Species," his most famous book, was published. His account of how he came to write it is reprinted in "The Naturalist," one of the six volumes of "Little Masterpieces of Science," published by Doubleday, Page & Co., New York.]

In the autumn of 1864 I finished a long paper on "Climbing Plants," and sent it to the Linnæan Society. The writing of this paper cost me four months; but I was so unwell when I received the proof-sheets that I was forced to leave them very badly and often obscurely expressed.

The paper was little noticed, but when in 1875 it was corrected and published as a separate book it sold well. I was led to take up this subject by reading a short paper by Asa Gray, published in 1858. He sent me seeds, and on raising some plants I was so much fascinated and perplexed by the revolving movements of the tendrils and stems, which movements are really very simple, though appearing at first sight very complex, that I procured various other kinds of climbing plants, and studied the whole subject. I was all the more attracted to it, from not being at all satisfied with the explanation which Henslow gave us in his lectures, about twining plants, namely, that they had a natural tendency to grow up in a spire. This explanation proved quite erroneous. Some of the adaptations displayed by climbing plants are as beautiful as those of orchids for ensuring cross-fertilisation.

My "Variation of Animals and Plants under Domestication" was begun, as already stated, in the beginning of 1860, but was not published until the beginning of 1868. It was a big book, and cost me four years and two months' hard labour. It gives all my observations and an immense number of facts collected from various sources, about our domestic productions. In the second volume the causes and laws of variation, inheritance, etc., are discussed as far as our present state of knowledge permits. Toward the end of the work I give my well-

abused hypothesis of Pangenesis. An unverified hypothesis is of little or no value; but if any one should hereafter be led to make observations by which some such hypothesis could be established, I shall have done good service, as an astonishing number of isolated facts can be thus connected together and rendered intelligible. In 1875 a second and largely corrected edition, which cost me a good deal of labour, was brought out.

My "Descent of Man" was published in February, 1871. As soon as I had become, in the year 1837 or 1838, convinced that species were mutable productions, I could not avoid the belief that man must come under the same law. Accordingly I collected notes on the subject for my own satisfaction, and not for a long time with any intention of publishing. Although in the "Origin of Species" the derivation of any particular species is never discussed, yet I thought it best, in order that no honourable man should accuse me of concealing my views, to add that by the work "light would be thrown on the origin of man and his history." It would have been useless and injurious to the success of the book to have paraded, without giving any evidence, my conviction with respect to his origin.

But when I found that many naturalists fully accepted the doctrine of the evolution of species, it seemed to me advisable to work up such notes as I possessed, and to publish a

special treatise on the origin of man. I was the more glad to do so, as it gave me an opportunity of fully discussing sexual selection — a subject which had always greatly interested me. This subject, and that of the variation of our domestic productions, together with the causes and laws of variation, inheritance, and the intercrossing of plants, are the sole subjects which I have been able to write about in full, so as to use all the materials which I have collected. The "Descent of Man" took me three years to write, but then as usual some of this time was lost by ill health, and some was consumed by preparing new editions and other minor works. A second and largely corrected edition of the "Descent" appeared in 1874.

Observes His First Child

My first child was born on December 27, 1839, and I at once commenced to make notes on the first dawn of the various expressions which he exhibited, for I felt convinced, even at this early period, that the most complex and fine shades of expression must all have had a gradual and natural origin. During the summer of the following year, 1840, I read Sir Charles Bell's admirable work on expression, and this greatly increased the interest which I felt in the subject, though I could not at all agree with his belief that various muscles had been specially created for the sake of expression. From this time forward, I occasionally attended to the

subject, both with respect to man and our domesticated animals.

In the summer of 1860 I was idling and resting near Hatfield, where two species of Drosera [sundew] abound; and I noticed that numerous insects had been entrapped by the leaves. I carried home some plants, and on giving them insects saw the movements of the tentacles, and this made me think it probable that the insects were caught for some special purpose. Fortunately a crucial test occurred to me, that of placing a large number of leaves in various nitrogenous and non-nitrogenous fluids of equal density; and as soon as I found that the former alone excited energetic movements, it was obvious that here was a fine new field for investigation.

Examines His own Mind and Character

I have now mentioned all the books which I have published, and these have been the milestones in my life, so that little remains to be said. I am not conscious of any change in my mind during the last thirty years, excepting in one point presently to be mentioned; nor, indeed could any change have been expected unless one of general deterioration. But my father lived to his eighty-third year with his mind as lively as it ever was, and all his faculties undimmed; and I hope that I may die before my mind fails to a sensible extent. I think that I have become a little more skilful in

guessing right explanations, and in devising experimental tests; but this may probably be the result of mere practice, and of a larger store of knowledge. I have as much difficulty as ever in expressing myself clearly and concisely; and this difficulty has caused me a very great loss of time; but it has had the compensating advantage of forcing me to think long and intently about every sentence, and thus I have been led to see errors in reasoning and in my own observations or those of others.

There seems to be a sort of fatality in my mind leading me to put at first my statement or proposition in a wrong or awkward form. Formerly I used to think about my sentences before writing them down; but for several years I have found that it saves time to scribble in a vile hand whole pages as quickly as I possibly can, contracting half the words, and then correct deliberately. Sentences thus scribbled down are often better ones than I could have written deliberately.

Having said thus much about my manner of writing, I will add that with my large books I spend a good deal of time over the general arrangement of the matter. I first make the rudest outline in two or three pages, and then a larger one in several pages, a few words or one word standing for a whole discussion or series of facts. Each one of these headings is again enlarged and often transferred before I begin to write *in extenso*. As in several of my books

facts observed by others have been very extensively used, and as I have always had several quite distinct subjects in hand at the same time, I may mention that I keep from thirty to forty large portfolios, in cabinets with labelled shelves, into which I can at once put a detached reference or memorandum. I have bought many books, and at their ends I make an index of all the facts that concern my work; or, if the book is not my own, write out a separate abstract, and of such abstracts I have a large drawer full. Before beginning on any subject I look to all the short indexes and make a general and classified index, and by taking the one or more proper portfolios I have all the information collected during my life ready for use.

I have said that in one respect my mind has changed during the last twenty or thirty years. Up to the age of thirty, or beyond it, poetry of many kinds, such as the works of Milton, Gray, Byron, Wordsworth, Coleridge, and Shelley. gave me great pleasure, and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. I have also said that formerly pictures gave me considerable, and music very great, delight. But now for many years I cannot endure to read a line of poetry: I have tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures or music. Music generally sets me thinking too energetically on what I have been at work

on, instead of giving me pleasure. I retain some taste for fine scenery, but it does not cause me the exquisite delight which it formerly did. On the other hand, novels which are works of the imagination, though not of a very high order, have been for years a wonderful relief and pleasure to me, and I often bless all novelists. A surprising number have been read aloud to me, and I like all if moderately good, and if they do not end unhappily — against which a law ought to be passed. A novel, according to my taste, does not come into the first class unless it contains some person whom one can thoroughly love, and if a pretty woman all the better.

This curious and lamentable loss of the higher æsthetic tastes is all the odder, as books on history, biographies, and travels (independently of any scientific facts which they may contain), and essays on all sorts of subjects interest me as much as ever they did. My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I cannot conceive. A man with a mind more highly organised or better constituted than mine, would not, I suppose, have thus suffered; and if I had to live my life again, I would have made a rule to read some poetry and listen to some music at least once every week; for perhaps the parts

of my brain now atrophied would thus have been kept active through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature.

My books have sold largely in England, have been translated into many languages, and passed through several editions in foreign countries. I have heard it said that the success of a work abroad is the best test of its enduring value. I doubt whether this is at all trustworthy; but judged by this standard my name ought to last for a few years. Therefore it may be worth while to try to analyse the mental qualities and the conditions on which my success has depended; though I am aware that no man can do this correctly.

I have no great quickness of apprehension or wit which is so remarkable in some clever men, for instance, Huxley. I am therefore a poor critic: a paper or book, when first read, generally excites my admiration, and it is only after considerable reflection that I perceive the weak points. My power to follow a long and purely abstract train of thought is very limited; and therefore I could never have succeeded with metaphysics or mathematics. My memory is extensive, yet hazy: it suffices to make me cautious by vaguely telling me that I have observed or read something opposed to the conclusion which I am drawing, or on the

other hand in favour of it; and after a time I can generally recollect where to search for my authority. So poor in one sense is my memory, that I have never been able to remember for more than a few days a single date or a line of poetry.

Some of my critics have said, "Oh, he is a good observer, but he has no power of reasoning!" I do not think that this can be true, for the "Origin of Species" is one long argument from the beginning to the end, and it has convinced not a few able men. No one could have written it without having some power of reasoning. I have a fair share of invention, and of common sense or judgment such as every fairly successful lawyer or doctor must have, but not, I believe, in any higher degree.

On the favourable side of the balance, I think that I am superior to the common run of men in noticing things which easily escape attention, and in observing them carefully. My industry has been nearly as great as it could have been in the observation and collection of facts. What is far more important, my love of natural science has been steady and ardent.

This pure love has, however, been much aided by the ambition to be esteemed by my fellow naturalists. From my early youth I have had the strongest desire to understand or explain whatever I observed, — that is, to group all facts under some general laws. These causes combined have given me the patience to reflect

or ponder for any number of years over any unexplained problem. As far as I can judge I am not apt to follow blindly the lead of other men. I have steadily endeavoured to keep my mind free so as to give up any hypothesis, however much beloved (and I cannot resist forming one on every subject), as soon as facts are shown to be opposed to it. Indeed, I have had no choice but to act in this manner, for with the exception of the coral reefs, I cannot remember a single first-formed hypothesis which had not after a time to be given up or greatly modified. This has naturally led me to distrust greatly deductive reasoning in the mixed sciences. On the other hand, I am not very sceptical — a frame of mind which I believe to be injurious to the progress of science. A good deal of scepticism in a scientific man is advisable to avoid much loss of time, but I have met with not a few men, who, I feel sure, have often thus been deterred from experiment or observations which would have proved directly or indirectly serviceable. . . .

My habits are methodical, and this has been of not a little use for my particular line of work. Lastly, I have had ample leisure from not having to earn my own bread. Even ill-health, though it has annihilated several years of my life, has saved me from the distractions of society and amusement.

Therefore my success as a man of science, whatever this may have amounted to, has been

determined, as far as I can judge, by complex and diversified mental qualities and conditions. Of these, the most important have been, the love of science, unbounded patience in long reflecting over any subject, industry in observing and collecting facts, and a fair share of invention as well as of common sense. With such moderate abilities as I possess, it is truly surprising that I should have influenced to a considerable extent the belief of scientific men on some important points.

THOMAS HENRY HUXLEY

[Professor Huxley was eminent as a naturalist, an educator, and a philosophical critic. His special field of investigation was that of comparative anatomy, in which he came upon many proofs of evolution. This led him to enlist as Darwin's chief expounder and defender when "The Origin of Species" appeared. No scientific writer has surpassed Huxley in clearness, wit, and force. Literature proper derives its main charm from treating the highest interests of man, his worthiest feelings, his best sentiments. That charm Huxley transferred to his pages by keeping steadily in view how new knowledge may mean more happiness, dignity, and justice for mankind. He died on June 29, 1895, in his seventy-first year.

His works include "Man's Place in Nature," "Elementary Physiology," "Physiography," "Lay Sermons, Addresses and Reviews," together with nine volumes of Essays, containing his latest and most characteristic thought. The passages from his autobiography are taken from the volume entitled "Methods and Results." All are published by D. Appleton & Co., New York. The same house publishes his "Life and Letters," edited by his son, Leonard Huxley, copyright, 1900. some of the pages which follow, drawn from that work, appear by the permission of the publishers. —Ed.]

Childhood

I was born about eight o'clock in the morning on the 4th of May, 1825, at Ealing, which was, at that time, as quiet a little country village as could be found within half a dozen miles of Hyde Park Corner. Now it is a suburb of London, with, I believe, thirty thousand inhabitants. My father was one of the masters in

a large semi-public school which at one time had a high reputation. I am not aware that any portents preceded my arrival in this world, but, in my childhood, I remember hearing a traditional account of the manner in which I lost the chance of an endowment of great practical value. The windows of my mother's room were open, in consequence of the unusual warmth of the weather. For the same reason, probably, a neighbouring beehive had swarmed, and the new colony, pitching on the window-sill, was making its way into the room when the horrified nurse shut down the sash. If that well-meaning woman had only abstained from her ill-timed interference, the swarm might have settled on my lips, and I should have been endowed with that mellifluous eloquence which, in this country, leads far more surely than worth, capacity, or honest work to the highest places in Church and State. But the opportunity was lost, and I have been obliged to content myself through life with saying what I mean in the plainest of plain language, than which, I suppose, there is no habit more ruinous to a man's prospects of advancement.

AT SCHOOL

My regular school training was of the briefest, perhaps fortunately, for though my way of life has made me acquainted with all sorts and conditions of men, from the highest to the lowest, I deliberately affirm that the society

I fell into at school was the worst I have ever known. We boys were average lads, with much the same inherent capacity for good and evil as any others; but the people who were set over us cared about as much for our intellectual and moral welfare as if they were baby-farmers. We were left to the operation of the struggle for existence among ourselves, and bullying was the least of the ill practices current among us. Almost the only cheerful reminiscence in connection with the place which arises in my mind is that of a battle I had with one of my classmates, who had bullied me until I could stand it no longer. I was a very slight lad, but there was a wild-cat element in me which, when roused, made up for lack of weight, and I licked my adversary effectually. However, one of my first experiences of the extremely rough-and-ready nature of justice, as exhibited by the course of things in general, arose out of the fact that I — the victor — had a black eye, while he — the vanquished — had none, so that I got into disgrace and he did not. We made it up, and thereafter I was unmolested. One of the greatest shocks I ever received in my life was to be told a dozen years afterward by the groom who brought me my horse in a stable-yard in Sydney that he was my quondam antagonist. He had a long story of family misfortune to account for his position, but at that time it was necessary to deal very cautiously with mysterious strangers in New South

Wales and on inquiry I found that the unfortunate young man had not only been "sent out," but had undergone more than one colonial conviction.

STUDIES MEDICINE

As I grew older, my great desire was to be a mechanical engineer, but the fates were against this, and, while very young, I commenced the study of medicine under a medical brother-in-law. But, though the Institute of Mechanical Engineers would certainly not own me, I am not sure that I have not all along been a sort of mechanical engineer *in partibus infidelium* [in unbelieving countries]. I am now occasionally horrified to think how very little I ever knew or cared about medicine as the art of healing. The only part of my professional course which really and deeply interested me was physiology, which is the mechanical engineering of living machines; and, notwithstanding that natural science has been my proper business, I am afraid there is very little of the genuine naturalist in me. I never collected anything, and species work was always a burden to me; what I cared for was the architectural and engineering part of the business, the working out the wonderful unity of plan in the thousands and thousands of diverse living constructions, and the modifications of similar apparatuses to serve diverse ends. The extraordinary attraction I felt toward the study of the intricacies of living

structure nearly proved fatal to me at the outset. I was a mere boy — I think between thirteen and fourteen years of age — when I was taken by some older student friends of mine to the first post-mortem examination I ever attended. All my life I have been most unfortunately sensitive to the disagreeables which attend anatomical pursuits, but on this occasion my curiosity overpowered all other feelings, and I spent two or three hours in gratifying it. I did not cut myself, and none of the ordinary symptoms of dissection-poison supervened, but poisoned I was somehow, and I remember sinking into a strange state of apathy. By way of a last chance, I was sent to the care of some good, kind people, friends of my father's, who lived in a farmhouse in the heart of Warwickshire. I remember staggering from my bed to the window on the bright spring morning after my arrival, and throwing open the casement. Life seemed to come back on the wings of the breeze, and to this day the faint odour of wood-smoke, like that which floated across the farm-yard in the early morning, is as good to me as the "sweet south upon a bed of violets." I soon recovered, but for years I suffered from occasional paroxysms of internal pain, and from that time my constant friend, hypochondriacal dyspepsia, commenced his half century of co-tenancy of my fleshly tabernacle.

Looking back on my years as a student, I am sorry to say that I do not think that any

account of my doings then would tend to edification. In fact, I should distinctly warn ingenuous youth to avoid imitating my example. I worked extremely hard when it pleased me, and when it did not — which was a very frequent case — I was extremely idle (unless making caricatures of one's pastors and masters is to be called a branch of industry), or else wasted my energies in wrong directions. I read everything I could lay hands upon, including novels, and took up all sorts of pursuits to drop them again quite as speedily. No doubt it was very largely my own fault, but the only instruction from which I ever obtained the proper effect of education was that which I received from Mr. Wharton Jones, who was the lecturer on physiology at the Charing Cross School of Medicine. The extent and precision of his knowledge impressed me greatly, and the severe exactness of his method of lecturing was quite to my taste. I do not know that I have ever felt so much respect for anybody as a teacher before or since. I worked hard to obtain his approbation, and he was extremely kind and helpful to the youngster who, I am afraid, took up more of his time than he had any right to do. It was he who suggested the publication of my first scientific paper — a very little one — in the *Medical Gazette* of 1845, and most kindly corrected the literary faults which abounded in it, short as it was; for at that time, and for many years afterward, I detested

the trouble of writing, and would take no pains over it.

SEEKS A NAVAL APPOINTMENT

It was in the early spring of 1846 that, having finished my obligatory medical studies and passed the first Bachelor of Medicine examination at the London University, I was talking to a fellow-student, and wondering what I should do to meet the imperative necessity for earning my own bread, when my friend suggested that I should write to Sir William Burnett, at that time Director-General for the Medical Service of the Navy, for an appointment. I thought this rather a strong thing to do, as Sir William was personally unknown to me, but my cheery friend would not listen to my scruples, so I went to my lodgings and wrote the best letter I could devise. A few days afterward I received the usual official circular of acknowledgment, but at the bottom there was written an instruction to call at Somerset House on such a day. I thought that looked like business, so at the appointed time I called and sent in my card, while I waited in Sir William's anteroom. He was a tall, shrewd-looking old gentleman, with a broad Scotch accent — and I think I see him now as he entered with my card in his hand. The first thing he did was to return it, with the frugal reminder that I should probably find it useful on some other occasion. The second was to ask whether I was an Irishman.

I suppose the air of modesty about my appeal must have struck him. I satisfied the Director-General that I was English to the backbone, and he made some inquiries as to my student career, finally desiring me to hold myself ready for examination. Having passed this, I was in Her Majesty's Service, and entered on the books of Nelson's old ship, the *Victory*, for duty at Haslar Hospital, about a couple of months after I made my application.

My official chief at Haslar was a very remarkable person, the late Sir John Richardson, an excellent naturalist, and far-famed as an indomitable arctic traveller. He was a silent, reserved man, outside the circle of his family and intimates; and, having a full share of youthful vanity, I was extremely disgusted to find that "Old John," as we irreverent youngsters called him, took not the slightest notice of my worshipful self either the first time I attended him, as it was my duty to do, or for some weeks afterward. I am afraid to think of the lengths to which my tongue may have run on the subject of the churlishness of the chief, who was, in truth, one of the kindest-hearted, and most considerate of men. But one day, as I was crossing the hospital square, Sir John stopped me, and heaped coals of fire on my head by telling me that he had tried to get me one of the resident appointments, much coveted by the assistant-surgeons, but that the Admiralty had put in another man. "However," said he

"I mean to keep you here till I can get you something you will like," and turned upon his heel without waiting for the thanks I stammered out. That explained how it was I had not been packed off to the West Coast of Africa like some of my juniors, and why, eventually, I remained altogether seven months at Haslar.

VOYAGE ON THE "RATTLESNAKE"

After a long interval, during which "Old John" ignored my existence almost as completely as before, he stopped me again as we met in a casual way, and describing the service on which the *Rattlesnake* was likely to be employed, said that Captain Owen Stanley, who was to command the ship, had asked him to recommend an assistant surgeon who knew something of science; would I like that? Of course I jumped at the offer. "Very well, I give you leave; go to London at once and see Captain Stanley." I went, saw my future commander, who was very civil to me, and promised to ask that I should be appointed to his ship, as in due time I was.

Life on board Her Majesty's ships in those days was a very different affair from what it is now, and ours was exceptionally rough, as we were often many months without receiving letters or seeing any civilised people but ourselves. In exchange, we had the interest of being about the last voyagers, I suppose, to whom it could be possible to meet with people

who knew nothing of fire-arms — as we did on the south coast of New Guinea — and of making acquaintance with a variety of interesting savage and semi-civilised people. But, apart from experience of this kind and the opportunities offered for scientific work, to me, personally, the cruise was extremely valuable. It was good for me to live under sharp discipline; to be down on the realities of existence by living on bare necessaries; to find out how extremely well worth living life seemed to be when one woke up from a night's rest on a soft plank, with the sky for canopy and cocoa and weevilly biscuit the sole prospect for breakfast; and, more especially, to learn to work for the sake of what I got for myself out of it, even if it all went to the bottom and I along with it. My brother officers were as good fellows as sailors ought to be and generally are, but, naturally, they neither knew nor cared anything about my pursuits, nor understood why I should be so zealous in pursuit of the objects which my friends, the middies, christened "Buffons," after the title conspicuous on a volume of the "Suites à Buffon" (the works, as a series, of Buffon, the naturalist), which stood on my shelf in the chart room.

During the four years of our absence, I sent home communication after communication to the Linnæan Society, with the same result as that obtained by Noah when he sent the raven out of his ark. Tired at last of hearing nothing

about them, I determined to do or die, and in 1849 I drew up a more elaborate paper and forwarded it to the Royal Society. This was my dove, if I had only known it. But owing to the movements of the ship, I heard nothing of that either until my return to England in the latter end of the year 1850, when I found that it was printed and published and that a huge packet of separate copies awaited me. When I hear some of my young friends complain of want of sympathy and encouragement, I am inclined to think that my naval life was not the least valuable part of my education.

CAREER SINCE THE VOYAGE

Three years after my return were occupied by a battle between my scientific friends on the one hand and the Admiralty on the other, as to whether the latter ought, or ought not, to act up to the spirit of a pledge they had given to encourage officers who had done scientific work by contributing to the expense of publishing mine. At last the Admiralty, getting tired, I suppose, cut short the discussion by ordering me to join a ship, which thing I declined to do. I desired to obtain a professorship of either physiology or comparative anatomy, and as vacancies occurred I applied, but in vain. My friend, Professor Tyndall, and I were candidates at the same time, he for the chair of physics and I for that of natural history in the University of Toronto, which, fortunately, as it turned out

would not look at either of us. I say fortunately, not from any lack of respect for Toronto, but because I soon made up my mind that London was the place for me, and hence I have steadily declined the inducements to leave it which have at various times been offered. At last, in 1854, on the translation of my warm friend, Edward Forbes, to Edinburgh, Sir Henry De la Beche, the Director-General of the Geological Survey, offered me the post Forbes vacated of paleontologist and lecturer on natural history. I refused the former point blank, and accepted the latter only provisionally, telling Sir Henry that I did not care for fossils, and that I should give up natural history as soon as I could get a physiological post. But I held the office for thirty-one years, and a large part of my work has been paleontological.

At that time I disliked public speaking, and had a firm conviction that I should break down every time I opened my mouth. I believe I had every fault a speaker could have (except talking at random or indulging in rhetoric), when I spoke to the first important audience I ever addressed, on a Friday evening at the Royal Institution, in 1852. Yet, I must confess to having been guilty, against my will, of as much public speaking as most of my contemporaries, and for the last ten years it ceased to be so much of a bugbear to me. I used to pity myself for having to go through this training, but I

am now more disposed to compassionate the unfortunate audiences, especially my ever-friendly hearers at the Royal Institution, who were the subjects of my oratorical experiments.

His Views Regarding Literary Faculty

[Mr George Bainton, in 1890, edited the "Art of Authorship," which was published in New York, by D. Appleton & Co., in an authorised edition. Professor Huxley's contribution was:]

I never had the good fortune to receive any guidance or instruction in the art of English composition. It is possibly for that reason I have always turned a deaf ear to the common advice to study good models, to "give days and nights to the study of Addison," and so on. Buffon said that a man's style is his very self, and in my judgment it ought to be so. The business of a young writer is not to ape Addison or Defoe, Hobbes or Gibbon, but to make his style himself, as they made their styles themselves. They were great writers, in the first place, because, by dint of learning and thinking, they had acquired clear and vivid conceptions about one or other of the many aspects of men or things. In the second place, because they took infinite pains to embody those conceptions in language exactly adapted to convey them to other minds. In the third place, because they possessed that purely artistic sense of rhythm and proportion which enabled them to add grace to force, and,

while loyal to truth, make exactness subservient to beauty.

I cannot say that the principles I have laid down have been my own guides; they are rather the result of a long experience. A considerable vein of indolence runs through my composition, and forty years ago there was nothing I disliked so much as the labour of writing. It was a task I desired to get over and done with as soon as possible. The result was such as might be expected.

If there is any merit in my English now, it is due to the fact that I have by degrees become awake to the importance of the three conditions of good writing which I have mentioned. I have learned to spare no labour upon the process of acquiring clear ideas — to think nothing of writing a page four or five times over if nothing less will bring the words which express all I mean; and to regard rhetorical verbosity as the deadliest and most degrading of literary sins. Any one who possesses a tolerably clear head and a decent conscience should be able, if he will give himself the necessary trouble, thus to fulfil the first two conditions of a good style. The carrying out of the third depends, neither on labour nor on honesty, but on that sense which is inborn in the literary artist, and can by no means be given to him who has it not as his birthright.

Letters

[The letters which follow are from the "Life and Letters of Thomas Henry Huxley," edited by his son, Leonard

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To his son Leonard, when at St. Andrew's University, on winning a scholarship tenable at Oxford:]

SOUTH KENSINGTON, April 21, 1879.

MY DEAR BOY: I was very glad to get your good news this morning, and I need not tell you whether Mater was pleased or not.

But the light of nature doth not inform us of the value and duration of the Guthrie scholarship — and from a low and material point of view I should like to be informed on that subject. However, this is mere "matter of detail" as the Irishman said when he was asked *how* he had killed his landlord. The pleasure to us is that you have made good use of your opportunities, and finished this first stage of your journey so creditably.

I am about to write to the Master of Balliol (Rev. Dr. Jowett) for advice as to your future proceedings. In the meanwhile, go in for the enjoyment of your holiday with a light heart. You have earned it.

Ever your loving father.

HIS CHIEF SCIENTIFIC CONTEMPORARIES IN ENGLAND

[The Bishop of Ripon asked Huxley for brief characterisations of modern leaders of science in England. Huxley responded and added:]

4 MARLBOROUGH PLACE, June 16, 1887.

MY DEAR BISHOP OF RIPON,

I shall be very glad if I can be of any use to you now and always. But it is not an easy task

to put into half a dozen sentences, up to the level of your own vigorous English, a statement that shall be unassailable from the point of view of a scientific fault-finder — which shall be intelligible to the general public and yet accurate.

I have made several attempts and enclose the final result. I think the substance is all right, and though the form might certainly be improved, I leave that to you. When I get to a certain point of tinkering my phrases, I have to put them aside for a day or two.

Will you allow me to suggest that it might be better not to name any living man? The temple of modern science has been the work of many labourers not only in our own but in other countries. Some have been more busy in shaping and laying the stones, some in keeping off the foes to all builders, some prophetwise in indicating the course of the science of the future. It would be hard to say who has done best service. As regards Dr. Joule, for example, no doubt he did more than any one else to give the doctrine of the conservation of energy precise expression, but Mayer and others run him hard.

Of deceased Englishmen who belong to the first half of the Victorian epoch, I should say that Faraday, Lyell, and Darwin had exerted the greatest influence, and al three were models of the highest and best clas of physical philosophers.

As for me, in part from force of circumstance and in part from a conviction I could be of

most use in that way, I have played the part of something between maid-of-all-work and gladiator-general for science, and deserve no such prominence as you have assigned to me.

AS TO CERTAINTY

[In July, 1890, Sir J. G. T. Sinclair wrote to him, calling his attention to a statement of Babbage's that after a certain point his famous calculating machine, contrary to all expectation, suddenly introduced a new principle of numeration into a series of numbers, and asking what effect this phenomenon had upon the theory of induction. Huxley replied:]

EASTBOURNE, July 21, 1890.

I knew Mr. Babbage, and am quite sure that he was not the man to say anything on the topic of calculating machines which he could not justify. I do not see that what he says affects the philosophy of induction as rightly understood. No induction, however broad its basis, can confer certainty — in the strict sense of the word. The experience of the whole human race through innumerable years has shown that stones unsupported fall to the ground, but that does not make it certain that any day next week unsupported stones will not move the other way. All that it does justify is the very strong expectation, which hitherto has been invariably verified, that they will do just the contrary.

Only one absolute certainty is possible to man, namely, that at any given moment the feeling which he has exists. All other so-called certainties are beliefs of greater or less intensity.

Do not suppose that I am following Dr. Abernethy's famous prescription, "take my pills," if I refer you to an essay of mine on Descartes, and a little book on Hume, for the fuller discussion of these points. . . .

LESSONS FROM A GRAIN OF WHEAT, A TURNIP, A SHEEP

[The following letter to Mr. J. Harrison was written in response to inquiries on behalf of the Easingwold Agricultural Club:]

EASTBOURNE, April 4, 1891.

I am afraid that my opinion on the subject of your inquiry is worth very little, my ignorance of practical agriculture being profound. However there are some general principles which apply to all technical training. The first of these, I think, is that practice is to be learned only by practice. The farmer must be made by and through farm work. I believe I might be able to give you a fair account of a bean plant and of the manner and condition of its growth, but if I were to try to raise a crop of beans, your club would probably laugh consumedly at the result. Nevertheless, I believe that you practical people would be all the better for the scientific knowledge which does not enable me to grow beans. It would keep you from attempting hopeless experiments, and would enable you to take advantage of the innumerable hints which Dame Nature gives to people who live in direct contact with things. And this

leads me to the second great principle which I think applies to all technical teaching for school-boys and school-girls, — that they should be led from the observation of the commonest facts to general scientific truths. If I were called upon to frame a course of elementary instruction preparatory to agriculture, I am not sure that I should attempt chemistry, botany, physiology, or geology, as such. It is a method fraught with the danger of spending too much time and attention on abstraction and theories, on words and notions instead of things. The history of a bean, of a grain of wheat, of a sheep, of a pig, or of a cow, properly treated — with the introduction of the elements of chemistry, physiology, and so on as they come in — would give all the elementary science which is needed for the comprehension of the processes of agriculture in a form easily assimilated by the youthful mind, which loathes everything in the shape of long words and abstract notions, and small blame to it. . . .

ADVISES A YOUNG MAN

[To a young man who asked his advice as to throwing up his business and plunging into literature or science:]

EASTBOURNE, November 5, 1892.

I am very sorry that the pressure of other occupations has prevented me from sending an earlier reply to your letter.

In my opinion a man's first duty is to find a

way of supporting himself, thereby relieving other people of the necessity of supporting him. Moreover, the learning to do work of practical value in the world, in an exact and careful manner, is of itself a very important education, the effects of which make themselves felt in all other pursuits. The habit of doing that which you do not care about when you would much rather be doing something else, is invaluable. It would have saved me a frightful waste of time if I had ever had it drilled into me in youth.

Success in any scientific career requires an unusual equipment of capacity, industry, and energy. If you possess that equipment you will find leisure enough, after your daily commercial work is over, to make an opening in the scientific ranks for yourself. If you do not, you had better stick to commerce. Nothing is less to be desired than the fate of a young man who, as the Scotch proverb says, in "trying to make a spoon spoils a horn," and becomes a mere hanger-on in literature or in science, when he might have been a useful and valuable member of society in other occupations.

I think your father ought to see this letter.

PROFESSOR SIMON NEWCOMB

[Professor Newcomb, of Washington, the acknowledged dean of science in America, is an astronomer of the first rank. He has received the highest honors at home and abroad. His writings are not only addressed to the learned, but to the intelligent public, by virtue of rare expository power. His works include, "Popular Astronomy," "Elements of Astronomy," "The Stars," "Astronomy for Everybody." His "Reminiscences," published by Houghton, Mifflin & Co., Boston, 1905, and copyright by the author, contain in their first chapter the following pages. They are here presented by the kind permission of the author and his publishers. — ED.]

I DATE my birth into the world of sweetness and light on one frosty morning in January, 1857, when I took my seat between two well-known mathematicians, before a blazing fire in the office of the "Nautical Almanac" at Cambridge, Mass. I had come on from Washington, armed with letters from Professor Henry and Mr. Hilgard, to seek a trial as an astronomical computer. The men beside me were Professor Joseph Winlock, the superintendent, and Mr. John D. Runkle, the senior assistant in the office. I talked of my unsuccessful attempt to master the "Mécanique Céleste" [Mechanism of the Heavens] of Laplace without other preparation than that afforded by the most meagre text-books of elementary mathematics of that period. Runkle spoke of the translator as "the Captain." So familiar a designation

of the great Bowditch — LL. D. and member of the Royal Societies of London, Edinburgh, and Dublin — quite shocked me.

I was then in my twenty-second year, but it was the first time I had ever seen any one who was familiar with the "Mécanique Céleste." I looked with awe upon the assistants who filed in and out as upon men who had all the mysteries of gravitation and the celestial motions at their fingers' ends. I should not have been surprised to learn that even the Hibernian who fed the fire had imbibed so much of the spirit of the place as to admire the genius of Laplace and Lagrange. My own rank was scarcely up to that of a tyro; but I was a few weeks later employed on trial as computer at a salary of thirty dollars a month.

How could an incident so simple and an employment so humble be in itself an epoch in one's life — an entrance into a new world? To answer this question some account of my early life is necessary. The interest now taken in questions of heredity and in the study of the growing mind of the child may excuse a word about my ancestry and early training.

Ancestry

Though born in Nova Scotia, I am of almost pure New England descent. The first Simon Newcomb, from whom I am of the sixth generation, was born in Massachusetts or Maine about 1666, and died at Lebanon, Conn., in 1745. His

descendants had a fancy for naming their eldest sons after him, and but for the chance of my father being a younger son, I should have been the sixth Simon in unbroken lineal descent.

Among my paternal ancestors none, so far as I know, with the exception of Elder Brewster, were what we should now call educated men. Nor did any other of them acquire great wealth, hold a high official position, or do anything to make his name live in history. On my mother's side are found New England clergymen and an English Nonconformist preacher, named Prince, who is said to have studied at Oxford toward the end of the seventeenth century, but did not take a degree. I do not know of any college graduate in the list.

Until I was four years old I lived in the house of my paternal grandfather, about two miles from the pretty little village of Wallace, at the mouth of the river of that name. He was, I believe, a stonecutter by trade and owner of a quarry which has since become important; but tradition credits him with unusual learning and with having at some time taught school.

My maternal grandfather was "Squire" Thomas Prince, a native of Maine, who had moved to Moncton, New Brunswick, early in life, and lived there the rest of his days. He was an upright magistrate, a Puritan in principle, and a pillar of the Baptist Church, highly respected throughout the province. He came from a long-lived family, and one so prolific

that it is said most of the Princes of New England are descended from it.

Father's Choice of Wife

My father was the most rational aud the most dispassionate of men. The conduct of his life was guided by a philosophy based on Combe's "Constitution of Man," and I used to feel that the law of the land was a potent instrument in shaping his paternal affections. His method of seeking a wife was so far unique that it may not be devoid of interest, even at this date. From careful study he had learned that the age at which a man should marry was twenty-five. A healthy and well-endowed offspring should be one of the main objects in view in entering the marriage state, and this required a mentally gifted wife. She must be of different temperament from his own and an economical housekeeper. So when he found the age of twenty-five approaching, he began to look about.

There was no one in Wallace who satisfied the requirements. He therefore set out afoot to discover his ideal. In those days and regions the professional tramp and mendicant were unknown, and every farmhouse dispensed its hospitality with an Arcadian simplicity little known in our times. Wherever he stopped overnight he made a critical investigation of the housekeeping, perhaps rising before the family for this purpose. He searched in vain until his road carried him out of the province. One

young woman spoiled any possible chance she might have had by a lack of economy in the making of bread. She was asked what she did with an unnecessarily large remnant of dough which she left sticking to the sides of the pan. She replied that she fed it to the horses. Her case received no further consideration.

The search had extended nearly a hundred miles when, early one evening, he reached what was then the small village of Moncton. He was attracted by the strains of music from a church, went into it, and found a religious meeting in progress. His eye was at once arrested by the face and head of a young woman playing on a melodeon, who was leading the singing. He sat in such a position that he could carefully scan her face and movements. As he continued this study the conviction grew upon him that here was the object of his search. That such should have occurred before there was any opportunity to inspect the doughpan may lead the reader to conclusions of his own. He enquired her name — Emily Prince. He cultivated her acquaintance, paid his addresses, and was accepted. He was fond of astronomy, and during the months of his engagement one of his favorite occupations was to take her out of an evening and show her the constellations. It is even said that, among the day dreams in which they indulged, one was that their firstborn might be an astronomer. Probably this was only a passing fancy, as I heard nothing of it during

my childhood. The marriage was in all respect a happy one, so far as congeniality of nature and mutual regard could go. Although the wife died at the early age of thirty-seven the husband never ceased to cherish her memory, and, so far as I am aware, never again thought of marrying.

My mother was the most profoundly and sincerely religious woman with whom I was ever intimately acquainted, and my father always entertained and expressed the highest admiration for her mental gifts, to which he attributed whatever talents his children might have possessed. The unfitness of her environment to her constitition is the saddest memory of my childhood. More I do not trust myself to say to the public, nor will the reader expect more of me.

My father followed, during most of his life, the precarious occupation of a country school teacher. It was then, as it still is in many thinly settled parts of the country, an almost nomadic profession, a teacher seldom remaining more than one or two years in the same place. Thus it happened that during the first fifteen years of my life, movings were frequent. My father tried his fortune in a number of places, both in Nova Scotia and Prince Edward Island. Our lot was made harder by the fact that his ideas of education did not coincide with those prevalent in the communities where he taught. He was a disciple and admirer of William Cobbett, and though he did not run so far counter to the

ideas of his patrons as to teach Cobbett's grammar at school, he always recommended it to me as the one by which alone I could learn to write good English. The learning of anything, especially of arithmetic and grammar, by the glib repetition of rules was a system that he held in contempt. With the public, ability to recite the rules of such subjects as those went farther than any actual demonstration of the power to cipher correctly or write grammatically.

A Primitive Community

So far as the economic condition of society and the general mode of living and thinking were concerned, I might claim to have lived in the time of the American Revolution. A railway was something read or heard about with wonder; a steamer had never ploughed the waters of Wallace Bay. Nearly everything necessary for the daily life of the people had to be made on the spot, and even at home. The work of the men and boys was "from sun to sun" — I might almost say from daylight to darkness — as they tilled the ground, mended the fences, or cut lumber, wood, and stone for export to more favoured climes. The spinning wheel and the loom were almost a necessary part of the furniture of any well-ordered house; the exceptions were among people rich enough to buy their own clothes, or so poor and miserable that they had to wear the cast-off rags of their more fortunate neighbours. The women and girls

sheared the sheep, carded the wool, spun the yarn, wove the homespun cloth, and made the clothes. In the haying season they amused themselves by joining in the raking of hay, in which they had to be particularly active if rain was threatened; but any man would have lost caste who allowed wife or daughter to engage in heavy work outside the house.

The contrast between the social conditions and those which surround even the poorest classes at the present day have had a profound influence upon my views of economic subjects. The conception which the masses of the present time have of how their ancestors lived in the early years of the century are so vague and shadowy as not to influence their conduct at the present time.

Early Instruction

What we now call school training, the pursuit of fixed studies at stated hours under the constant guidance of a teacher, I could scarcely be said to have enjoyed. For the most part, when I attended my father's school at all, I came and went with entire freedom, and this for causes which, as we shall see, he had reasons for deeming good.

It would seem that I was rather precocious. I was taught the alphabet by my aunts before I was four years old, and I was reading the Bible in class and beginning geography when I was six.

One curious feature of my reading I do not remember to have seen noticed in the case of

children. The printed words, for the most part, brought no well-defined images to my mind; none at least that were retained in their connection. I remember one instance of this. We were at Bedeque, Prince Edward Island. During the absence of my father, the school was kept for a time by Mr. Bacon. The class in reading had that chapter in the New Testament in which the treason of Judas is described. It was then examined on the subject. To the question what Judas did, no one could return an answer until it came my turn. I had a vague impression of some one hanging himself, and so I said quite at random that he hanged himself. It was with a qualm of conscience that I went to the head of the class.

Arithmetic was commenced at the age of five, my father drawing me to school day by day on a little sled during the winter. Just what progress I made at that time I do not recall. Long years afterward, my father, at my request, wrote me a letter describing my early education, extracts from which I shall ask permission to reproduce, instead of attempting to treat the matter myself. The letter, covering twelve closely written foolscap pages, was probably dashed off at a sitting without supposing any eye but my own would ever see it:

"June 8th, '58.

"I will now proceed to write, according to your request, about your early life.

"While in your fifth year, your mother spoke

several times of the propriety of teaching you the first rudiments of book-learning; but I insisted that you should not be taught the first letter until you became five. * I think, though, that at about four, or four and a half, I taught you to count, as far, perhaps, as 100.

"When a little over four and a half, one evening as I came home from school, you ran to me, and asked: Father, is not 4 and 4 and 4 and 4, 16? Yes, how did you find it out? You showed me the counterpane which was napped. The spot of four rows each way was the one you had counted up. After this, for a week or two, you spent a considerable number of hours every day, making calculations in addition and multiplication. The rows of naps being crossed and complexed in various ways, your greatest delight was to clear them out, find how many small ones were equal to one large one, and such like. After a space of two or three weeks we became afraid you would calculate yourself out of your head, and laid away the counterpane.

"Winter came, and passed along, and your birthday came; on that day, having a light hand-sled prepared, I fixed you on it, and away we went a mile and a half to school.

"According to my belief in educational matters that the slate should be put into the child's

* He had evidently forgotten the home instruction from my aunts, received more than a year previous to the date he mentions.

hand as soon as the book is, you of course had your slate, and commenced making figures and letters the first day.

"In all cases, after you had read and spelled a lesson, and made some figures, and worked a sum, suppose one hour's study, I sent you out, telling you to run about and play a good spell. To the best of my judgment you studied, during the five months that this school lasted, nearly four hours a day, two being at figures. . . .

"During the year that I taught at Bedeque, you studied about five hours a day in school; and I used to exercise you about an hour a day besides, either morning or evening. This would make six hours per day, nearly or quite two and a half hours of that time at numbers either at your slate or mentally. When my school ended here, you were six and a half years of age, and pretty well through the arithmetic. You had studied, I think, all the rules preceding including the cube root."

I had frequently heard, during my boyhood, of a supposed mental breakdown about this period, and had asked my father for a description of it in the letter from which I am quoting. On this subject the letter continues:

"You had lost all relish for reading, study, play, or talk. Sat most of the day flat on the floor or hearth. When sent of an errand, you would half the time forget what you went for.

I have seen you come back from Cale Schurman's* crying, and after asking you several times you would make out to answer you had not been all the way over because you forgot what you went for. You would frequently jump up from the corner, and ask some peculiar question. I remember three you asked me.

"1st. Father, does form mean shape? Yes. Has everything some shape? Yes. Can it be possible for anything to be made that would not have any shape? I answered no; and then showed you several things, explaining that they all had some shape or form. You now brightened up like a lawyer who had led on a witness with easy questions to a certain point, and who had cautiously reserved a thunderbolt question, to floor the witness at a proper time; proceeded with, 'Well, then, how could the world be without form when God made it?' . . .

"3rd. Does Cale Schurman's big ram know that he has such big crooked horns on him? Does he know it himself, I mean? Does he know himself that he has such horns on him?

"You were taken down suddenly I think about two or three days from the first symptoms until you were fairly in the corner. Your rise was also rapid, I think about a week (or perhaps two weeks) from your first recovery, until you seemed to show nothing unusual. From the

* The grandfather of President Schurman of Cornell University.

time you were taken down until you commenced recovery was about a month.

"We returned to Prince Edward Island, and after a few weeks I began to examine you in figures, and found you had forgotten nearly all you had ever learned. . . .

"While at New London I got an old work on astronomy; you were wonderfully taken with it, and read it with avidity. While here you read considerable in 'Goldsmith's History of England.' We lived two years in New London; I think you attended school nearly one year there. I usually asked you questions on the road going to school, in the morning, upon the history you had to read, or something you had studied the day previous. While there, you made a dozen or two of the folks raise a terrible laugh. I one evening lectured on astronomy at home; the house was pretty well filled, I suppose about twenty were present. You were not quite ten years old and small at that. Almost as soon as I was done you said: 'Father, I think you were wrong in one thing.' Such a roar of laughter almost shook the house.

"You were an uncommon child for *truth*. I never knew you to deviate from it in one single instance, either in infancy or youth.

"From your infancy you showed great physical courage in going along the woods or in places in the dark among cattle, and I am surprised at what you say about your fears of a stove-pipe and trees.

"Perhaps I should have said 'mental' instead of physical courage, for in one respect you were uncommonly deficient in that sort of courage necessary to perform bodily labour. Until nine or ten years of age you made a most pitiful attempt at any sort of bodily or rather handy work. . . .

"An extraordinary peculiarity in you was never to leap past a word you could not make out. I certainly never gave you any particular instructions about this, or the fact itself would not at the time have appeared so strange to me. I will name one case. After a return to Wallace (you were eleven) I, one day, on going from home for an hour or so, gave you a borrowed newspaper, telling you there was a fine piece; to read it, and tell me its contents when I returned. On my return you were near the house chopping wood. 'Well, Simon, did you read the piece?' 'No, sir.' 'Why not?' 'I came to a word I did not know.' This word was just about four lines from the commencement.

"At thirteen you read phrenology. I now often impressed upon you the necessity of bodily labour; that you might attain a strong and healthy physical system, so as to be able to stand long hours of study when you came to manhood, for it was evident to me that you would not labour with the hands for a business. On this account as much as on account of poverty. I hired you out for a large portion of the three years that we lived at Clements.

"At fifteen you studied Euclid, and were enraptured with it. It is a little singular that all this time you never showed any self-esteem; or spoke of getting into employment at some future day, among the learned. The pleasure of intellectual exercise in demonstrating or analysing a geometrical problem, or solving an algebraic equation, seemed to be your only object. No Junior, Seignour, or Sophomore class, with annual honours, was ever, I suppose, presented to your mind.

"Your almost intuitive knowledge of geography, navigation, and nautical matters in general caused me to think most ardently of writing to the Admiral at Halifax, to know if he would give you a place among the midshipmen of the navy; but my hope of seeing you a leading lawyer, and finally a judge on the bench, together with the possibility that your mother would not consent, and the possibility that you would not wish to go, deterred me; although I think I commenced a letter."

Early Reading

Among the books which profoundly influenced my mode of life and thought during the period embraced in the foregoing extracts were Fowler's "Phrenology" and Combe's "Constitution of Man." It may appear strange to the reader if a system so completely exploded as that of phrenology should have any value as a mental discipline. Its real value consisted, not in what

it taught about the position of the "organs," but in presenting a study of human nature which, if not scientific in form, was truly so in spirit. I acquired the habit of looking on the characters and capabilities of men as the result of their organisms. A hot and impulsive temper was checked by the reflection that it was beneath the dignity of human nature to allow a rush of blood to the organs of "combativeness" and "destructiveness" to upset one's mental equilibrium.

That I have gotten along in life almost without making (so far as I am aware) a personal enemy may be attributed to this early discipline, which lead me into the habit of dealing with antagonism and personal opposition as I would deal with any physical opposition — evade it, avoid it, or overcome it. It goes without saying, however, that no discipline of this sort will avail to keep the passions of a youth always in check, and my own were no exception. When about fifteen I once made a great scandal by taking out my knife in prayer meeting and assaulting a young man who, while I was kneeling down during the prayer, stood above me and squeezed my neck. He escaped with a couple of severe though not serious cuts in his hand. He announced his intention of thrashing me when we should meet again; so for several days thereafter I tried, so far as possible, in going afield to keep a pitchfork within reach, determined that if he tried the job and I failed to kill him, it would be be-

cause I was unable to do so. Fortunately for both of us he never made the attempt.

I read Combe's "Constitution of Man" when between ten and twelve years of age. Though based on the ideas of phrenology and not, I believe, of high repute as a system of philosophy, it was as good a moral tonic as I can imagine to be placed in the hands of a youth, however fallacious may have been its general doctrines. So far as I can recall, it taught that all individual and social ills were due to men's disregard of the laws of Nature, which were classified as physical and moral. Obey the laws of health and we and our posterity will all reach the age of one hundred years. Obey the moral law and social evils will disappear. Its reading was accompanied by some qualms of conscience, arising from the non-accordance of many of its tenets with those of the "Catechism" and the "New England Primer." The combination of the two, however, led to the optimistic feeling that all wrongs would be righted, every act of injustice punished, and truth and righteousness eventually triumph through the regular processes of Nature and Society. I have been led to abandon this doctrine only by much experience. . . .

In the direction of mathematical and physical science and reading generally, I may add something to what I have quoted from my father. My grandfather Simon had a small collection of books in the family. Among those purely

literary were several volumes of "The Spectator" and "Roderick Random." Of the former I read a good deal. The latter was a story which a boy who had scarcely read any other would naturally follow with interest. Two circumstances connected with the reading, one negative and the other positive, I recall. Looking into the book after attaining years of maturity, I found it to contain many incidents of a character that would not be admitted into a modern work. Yet I read it through without ever noticing or retaining any impression of the indelicate side of the story. The other impression was a feeling of horror that a man fighting a duel and finding himself, as he supposed, mortally wounded by his opponent, should occupy his mind with avenging his own death instead of making his peace with heaven.

Begins Mathematical Study

Three mathematical books were in the collection, Hammond's Algebra, Simpson's Euclid, and Moore's Navigator, the latter the predecessor of Bowditch. The first was a miserable book, and I think its methods, which were crude in the extreme, though not incorrect, were rather more harmful than beneficial. The queer diagrams in Euclid had in my early years so little attraction for me that my curiosity never led me to examine its text. I at length did so in consequence of a passage in the algebra which referred to the 47th proposition of the First Book. It occurred to

me to look into the book and see what this was. It was the first conception of mathematical proof that I had ever met with. I saw that the demonstration referred to a previous proposition, went back to that, and so on to the beginning. A new world of thought seemed to be opened. That principles so profound should be reached by methods so simple was astonishing. I was so enraptured that I explained to my brother Thomas while walking out of doors one day how the Pythagorean proposition, as it is now called, could be proved from first principles, drawing the necessary diagrams with a pencil on a piece of wood. I thought that even cattle might understand geometry could they only be communicated with and made to pay attention to it.

Some one at school had a copy of Mrs. Marcet's "Conversations on Natural Philosophy." With this book I was equally enraptured. Meagre and even erroneous though it was, it presented in a pleasing manner the first principles of physical science. I used to steal into the schoolhouse after hours to read a copy of the book, which belonged to one of the scholars, and literally devoured it in a few evenings.

My first undertaking in the way of scientific experiment was in the field of economics and psychology. When about fourteen I spent the winter in the house of an old farmer named Jefferson. He and his wife were a very kindly couple and took much interest in me. He was fond of his pipe, as most old farmers are. I

questioned whether anything else would not do just as well as tobacco to smoke, and whether he was not wasting his money by buying that article when a cheap substitute could be found. So one day I took his pipe, removed the remains of the tobacco ashes, and stuffed the pipe with tea leaves that had been steeped, and which in colour and general appearance looked much like tobacco. I took care to be around when he should again smoke. He lit the pipe as usual and smoked it with, seemingly, as much satisfaction as ever, only essaying the remark, "This tobacco tastes like tea." My conscience pricked me, but I could say nothing.

My father bought a copy of Lardner's "Popular Lectures on Science and Art." In this I first read of electricity. I recall an incident growing out of it. In Lardner's description of a Leyden jar, water is the only internal conductor. The wonders of the newly invented telegraph were then explained to the people in out of the way places by travelling lecturers. One of these came to Clements, where we then lived, with a lot of apparatus, amongst which was what I recognised as a Leyden jar. It was coated with tinfoil on the outside, but I did not see the inner coating, or anything which could serve as the necessary conductor. So with great diffidence I asked the lecturer while he was arranging his things, if he was not going to put water into the jar

"No, my lad," was his reply, "I put lightning into it."

I wondered how the "lightning" was going to be conveyed to the interior surface of the glass without any conductor, such as water, but was too much abashed to ask the question.

Moore's "Navigator" taught not only a very crude sort of trigonometry, but a good deal about the warship of his time. To a boy living on the seacoast, who naturally thought a ship of war one of the greatest works of man, the book was of much interest.

His Precocity Excites Wonder

Notwithstanding the intellectual pleasure which I have described, my boyhood was on the whole one of sadness. Occasionally my love of books brought a word of commendation from some visitor, perhaps a Methodist minister, who patted me on the head with a word of praise. Otherwise it caused only exclamations of wonder which were distasteful.

"You would n't believe what larnin' that boy has got. He has more larnin' than all the people around here put together," I heard one farmer say to another, looking at me, in my own view of the case, as if I were some monster misshapen in the womb. Instead of feeling that my bookish taste was something to be valued, I looked upon myself as a freak of nature whom Nature had cruelly formed to suffer from an abnormal constitution, and lamented that somehow I never could be like other boys.

The maladroitness described by my father, of

which I was fully conscious, added to the feeling of my unfitness for the world around me. The skill required on a farm was above my reach, where efficiency in driving oxen was one of the most valued of accomplishments. I keenly felt my inability to acquire even respectable mediocrity in this branch of the agricultural profession. It was mortifying to watch the dexterous motions of the whip and listen to the torrent of imperatives with which a young farmer would set a team of these stolid animals in motion after they had failed to respond to my gentle requests, though conveyed in the best of ox language.

I had indeed gradually formed, from reading, a vague conception of a different kind of world — a world of light — where dwelt men who wrote books and people who knew the men who wrote books — where lived boys who went to college and devoted themselves to learning, instead of driving oxen. I longed much to get into this world, but no possibility of doing so presented itself. I had no idea that it would be imbued with sympathy for a boy outside of it who wanted to learn. True, I had once read in some story, perhaps fictitious, how a nobleman had found a boy reading Newton's "Principia," and not only expressed his pleased surprise at the performance, but actually got the boy educated. But there was no nobleman in sight of the backwoods of Nova Scotia. I read in the autobiography of Franklin how he had made his way in life. But he was surrounded with

opportunities from which I was cut off. It does seem a little singular that, well known as my tastes were to those around me, we never met a soul to say, "That boy ought to be educated." So far as I know, my father's idea of making me a lawyer met with nothing but ridicule from the neighbours. Did not a lawyer have to know Latin and have money to pursue his studies? In my own day-dreams I was a farmer driving his own team; in my mother's a preacher, though she had regretfully to admit that I might never be good enough for this profession.

SIR ARCHIBALD GEIKIE

[Sir Archibald Geikie, director of the Geological Survey of the United Kingdom, is the most eminent living geologist. In the pages which follow, taken from "Geological Sketches at Home and Abroad," published in 1882 by the Macmillan Company, he tells us how as a boy he came to choose his life work. His story shows him to be a master of clear and delightful narration. He excels, too, as a popular expositor, notably in "The Story of a Boulder," and "The Scenery of Scotland Viewed in Connection with Its Physical Geology." His "Text-book of Geology," in two volumes, of which a new edition appeared in 1903, the standard treatise in the English language, is published by the Macmillan Company.— ED.]

MY FIRST GEOLOGICAL EXCURSION

IT IS an old story now, so far back, indeed, that I hardly like to reckon up the years that have since passed away. But clear and bright does it stand in my memory, notwithstanding, that quiet autumnal afternoon, with its long country ramble to an old quarry, the merry shouts of my schoolmates, the endless yarns we span by the way, and the priceless load of stones we bore homeward over those weary miles, when the sun had sunk, red and fiery, in the west, and the shadows of twilight began to deepen the gloom of the woods. Many a country ramble have I made since then, but none, perhaps, with so deep and hearty an enjoyment, for it opened up a new world, into which a fancy fresh from the

Arabian Nights and Don Quixote could adventurously ride forth.

Up to that time my leisure hours, after school lessons were learnt, and all customary games were played, had been given to laborious mechanical contrivances, based sometimes on most preposterous principles. For a while I believed I had discovered perpetual motion. Day and night the vision haunted me of a wheel turning, turning, in endless revolutions; and what was not this wheel to accomplish? It was to be the motive-power in every manufactory all through the country, to the end of time, to be called by my name, just as other pieces of mechanism bore the names of other inventive worthies, in that treasure of a book "The Century of Inventions." Among various contrivances I remember striving hard to construct a boat that should go through the water by means of paddles, to be worked by a couple of men, or, failing them, by a horse; but though I found (if my memory serve me) that my hero, the old Marquis of Worcester, had anticipated the invention by almost two hundred years, I could not succeed in getting the paddles to move except when the boat was out of the water, and so the grand contrivance, that might have made its discoverer famous in every harbour in the kingdom, fell to the ground.

Saturday afternoons were always observed by us as a consecrated holiday-time, all school-work being then consigned to a delightful

oblivion. To learn a lesson during these hours was regarded as something degenerate and wholly unworthy of the dignity of a schoolboy. Besides, we had always plenty of work of some kind to fill up the time, and what the nature of that work was to be for the ensuing Saturday had usually been determined long before the coveted Saturday came. Sometimes, if the weather was dull, my comrades repaired to my room (which we dignified as "the workshop") to hear a disquisition on the last invention, or to help if they could in removing some troublesome and apparently insuperable mechanical difficulty. Or we planned a glorious game of cricket, or golf, or football, that seldom came to a close until the evening grew too dark for longer play. In spring-time we would sally forth into the country to some well-remembered bank, where the primroses and violets bloomed earliest, and return at dusk, bringing many a bunch for those at home. The summer afternoons often found us loitering, rod in hand, along the margin of a shady streamlet, in whose deeper pools the silvery troutlet loved to feed. And it fed, truly, with little danger from us. The writhing worm (we never soared to the use of the fly), though ever so skilfully and unfeelingly twined round the hook, failed to allure the scaly brood, which we could see darting up and down the current without so much as a nibble at our tempting bait. Not so, however, with another member of that tribe, the little stickleback, or "beardie,"

as we called it, to which we had the most determined and unreasonable antipathy. The cry of "A beardie! a beardie!" from one of our party was the sign for every rod and stick to be thrown down on the bank, and a general rush to the spot where the enemy of the trout had been seen. Off went stockings and shoes, and in plunged the wearer, straight to the large stone in mid-channel under which the foe was supposed to be lurking. Cautiously were the fingers passed into the crevices and round the base of the stone, and the little victim, fairly caught at last in his den, was thrown in triumph to the bank, where many a stone was at hand to end his torments and his life.

A Visit to Quarries

'T is an old story, truly; but I remember as if it had been yesterday, how my Saturday employments were changed, and how the vagrant, careless fancies of the schoolboy passed into the settled purposes that have moulded the man. I had passed a Saturday afternoon alone, and next day as usual met my comrades at church. On comparing notes, I found that the previous afternoon they had set out for some lime-quarries, about four miles off, and had returned laden with wonders — plants of strange form, with scales, teeth, and bones of uncouth fishes, all embedded in the heart of the stone, and drawn out of a subterranean territory of almost fabulous extent and gloom. Could anything more marvellous

have been suggested to a youthful fancy? The caverns of the Genii, even that of the Wonderful Lamp, seemed not more to be coveted. At least the new cave had this great advantage over the old ones, that I was sure it was really true; a faint suspicion having begun to arise that, possibly, after all, the Eastern caverns might have no more tangible existence than on the pages of the story-book. But here, only four miles from my own door, was a real cavern, mysterious beyond the power of my friends to describe, inhabited by living men who toiled liked gnomes with murky faces and little lamps on their foreheads, driving wagons, and blasting open the rock in vast and seemingly impenetrable galleries, where the sullen reverberations boomed as it were for miles among endless gigantic pillars and sheets of Stygian water that stretched away deep and dark into fathomless gloom. And in that rock, wrapped up in its substance like mummies in their cerements, lay heaps of plants of wondrous kinds; some resembled those of our woods and streams, but there were many, the like to which my companions declared that even in our longest rambles they had never seen on bank, or brake, or hill; fishes, too, there were, with strong massive scales, very different from our trouts and minnows. Some of the spiny fins, indeed, just a little resembled our foe the "beardie." Very likely (thought I), the Genius of the cave, being a sensible fellow, has resolved to preserve his trout, and so with

a murrain on the beardies has buried them bodily in the rock.

But above all, in these dark subterranean recesses lurked the remains of gigantic reptiles; and one of the quarrymen possessed a terrific tusk and some fragmentary scales, which he would have sold to my friends could their joint purse have supplied the stipulated price.

My interest in the tale, of course, increased at every new incident; but when they came to talk of reptiles, the exuberant fancy could contain itself no longer. "Dragons! dragons!" I shouted, and rubbed my hands in an ecstasy of delight. "Dragons, boys, be sure they are, that have been turned into stone by the magic of some old necromancer."

They had found, too, in great abundance, what they had been told were "coprolites" — that is, as we afterward learnt, the petrified excrement of ancient fishes. "Copper *lites*," thought I, nay, perchance it might be *gold;* for who ever read of such a famous cavern with petrified forests, fishes, and dragons, that had not besides huge treasures of yellow gold?

So there and then we planned an excursion for the following Saturday. The days that intervened stretched themselves somehow to an interminable length. It seemed the longest week of my life, even though every sleeping and waking hour was crowded with visions of the wondrous cavern. At length the long

expected morning dawned, and soon brightened up into a clear, calm autumnal day.

A Second Excursion

We started off about noon; a goodly band of some eight or nine striplings, with two or three hammers, and a few pence amongst us, and no need to be home before dusk. An October sun shone merrily out upon us; the fields, bared of their sheaves, had begun to be again laid under the plough, and long lines of rich brown loam alternated with bands of yellow stubble, up and down which toiled many a team of steaming horses. The neighbouring woods, gorgeous in their tints of green, gold, and russet, sent forth clouds of rooks, whose noisy jangle, borne onward by the breeze, and mingling with the drone of the bee and the carol of the lark, grew mellow in the distance, as the cadence of a far-off hymn. We were too young to analyse the landscape, but not too young to find in every feature of it the intensest enjoyment. Moreover, our path lay through a district rich in historic associations. Watch-peels [fortified strongholds], castles, and towers looked out upon us as we walked, each with its traditionary tales, the recital of which formed one of our chief delights. Or if a castle lacked its story, our invention easily supplied the defect. And thus every part of the way came to be memorable in our eyes for some thrilling event real or imaginary — battles, stern and bloody, fierce encounters in single

combat, strange weird doings of antique wizards, and marvellous achievements of steel-clad knights, who rambled restlessly through the world to deliver imprisoned maidens.

Thus beguiled, the four miles seemed to shrink into one, and we arrived at length at the quarries. They had been opened, I found, along the slope of a gentle declivity. At the north end stood the kilns where the lime was burnt, the white smoke from which we used to see some miles away. About a quarter of a mile to the south lay the workings where my comrades had seen the subterranean men; and there, too, stood the engine that drew up the waggons and pumped out the water. Between the engine and the kilns the hillside had all been mined and exhausted; the quarrymen having gradually excavated their way southward to where we saw the smoking chimney of the engine-house. We made for a point midway in the excavations; and great indeed was our delight, on climbing a long bank of grass-grown rubbish, to see below us a green hollow, and beyond it a wall of rock, in the centre of which yawned a dark cavern, plunging away into the hill far from the light of day. My companions rushed down the slope with a shout of triumph. For myself, I lingered a moment on the top. With just a tinge of sadness in the thought, I felt that though striking and picturesque beyond anything of the kind I had ever seen, this cavern was after all only a piece of human handiwork. The

heaps of rubbish around me, with the smoking kilns at the one end and the clanking engine at the other, had no connection with beings of another world, but told only too plainly of ingenious, indefatigable man. The spell was broken at once and for ever, and as it fell to pieces, I darted down the slope and rejoined my comrades.

A Cave and Its Wonders

They had already entered the cave, which was certainly vast and gloomy enough for whole legions of gnomes. The roof, steep as that of a house, sloped rapidly into the hillside beneath a murky sheet of water, and was supported by pillars of wide girth, some of which had a third of their height, or more, concealed by the lake, so that the cavern, with its inclined roof and pillars, half sunk in the water, looked as though it had been rent and submerged by some old earthquake. Not a vestige of vegetation could we see save, near the entrance, some dwarfed scolopendriums and pale patches of moss. Not an insect, nor indeed any living thing seemed ever to venture down into this dreary den. Away it stretched to the right hand and the left, in long withdrawing vistas of gloom, broken, as we could faintly see, by the light which, entering from other openings along the hillside, fell here and there on some hoary pillar, and finally vanished into the shade.

It is needless to recall what achievements we

performed; how, with true boyish hardihood, we essayed to climb the pillars, or crept along the ledges of rock that overhung the murky water, to let a ponderous stone fall plump into the depths, and mark how long the bubbles continued to rise gurgling to the surface, and how long the reverberations of the plunge came floating back to us from the far-off recesses of the cave. Enough, that, having satisfied our souls with the wonders below ground, we set out to explore those above.

"But where are the petrified forests and fishes?" cried one of the party. "Here!" "Here!" was shouted in reply from the top of the bank by two of the ringleaders on the previous Saturday. We made for the heap of broken stones whence the voices had come, and there, truly, on every block and every fragment the fossils met our eyes, sometimes so thickly grouped together that we could barely see the stone on which they lay. I bent over the mound, and the first fragment that turned up (my first-found fossil) was one that excited the deepest interest. The commander-in-chief of the first excursion, who was regarded (perhaps as much from his bodily stature as for any other reason) an authority on these questions, pronounced my treasure-trove to be, unmistakably and unequivocally, a fish. True, it seemed to lack head and tail and fins; the liveliest fancy amongst us hesitated as to which were the scales; and in after years I learned that it was really a

vegetable — the seed-cone or catkin of a large extinct kind of club-moss; but, in the meantime, Tom had declared it to be a fish, and a fish it must assuredly be.

Seeing Better than Reading

The halo that broke forth from the Wizard's tomb when William of Deloraine and the Monk of St. Mary's heaved at midnight the ponderous stone was surely not brighter, certainly not so benign in its results, as the light that now seemed to stream into my whole being, as I disinterred from their stony folds these wondrous relics. Like other schoolboys, I had, of course, had my lessons on geology in the usual meagre, cut-and-dry form in which physical science was then taught in our schools. I could repeat a "Table of Formations," and remembered the pictures of some uncouth monsters on the pages of our text-books — one with goggle-eyes, no neck, and a preposterous tail; another with an unwieldy body, and no tail at all, for which latter defect I had endeavoured to compensate by inserting a long pipe into his mouth, receiving from our master (Ironsides, we called him) a hearty rap across the knuckles, as a recompense for my attention to the creature's comfort. But the notion that these pictures were the representations of actual, though now extinct monsters, that the matter-of-fact details of our text-books really symbolised living truths, and were not invented solely to distract the

brains and endanger the palms of schoolboys; nay, that the statements which seemed so dry and unintelligible in print were such as could be actually verified by our own eyes in nature, that beneath and beyond the present creation, in the glories of which we revelled, there lay around us the memorials of other creations not less glorious, and infinitely older, and thus that more, immensely more, than our books or our teachers taught us could be learnt by looking at nature for ourselves — all this was strange to me. It came now for the first time like a new revelation, one that has gladdened my life ever since.

We worked on industriously at the rubbish heap, and found an untold sum of wonders. The human mind in its earlier stages dwells on resemblances, rather than on differences. We identified what we found in the stones with that to which it most nearly approached in existing nature, and though many an organism turned up to which we could think of no analogue, we took no trouble to discriminate wherein it differed from others. Hence, to our imagination, the plants, insects, shells, and fishes of our rambles met us again in the rock. There was little that some one of the party could not explain, and thus our limestone became a more extraordinary conglomeration of organic remains, I will venture to say, than ever perturbed the brain of a geologist. It did not occur at the time to any of us to inquire why a perch came

to be embalmed among ivy and rose leaves; why a sea-shore whelk lay entwined in the arms of a butterfly; or why a beetle should seem to have been doing his utmost to dance a pirouette round the tooth of a fish. These questions came all to be asked afterward, and then I saw how egregiously erroneous had been our boyish identifications. But, in the meantime, knowing little of the subject, I believed everything, and with implicit faith piled up dragon-flies, ferns, fishes, beetle-cases, violets, seaweeds, and shells.

The shadows of twilight had begun to fall while we still bent eagerly over the stones. The sun, with a fiery glare, had sunk behind the distant hills, and the long lines of ruddy light that mottled the sky as he went down had crept slowly after him, and left the clouds to come trooping up from the east, cold, lifeless, and gray. The chill of evening now began to fall over everything, save the spirits of the treasure-seekers. And yet they, too, in the end succumbed. The ring of the hammer became less frequent, and the shout that announced the discovery of each fresh marvel seldomer broke the stillness of the scene. And, as the moanings of the night-wind swept across the fields, and rustled fitfully among the withered weeds of the quarry, it was wisely resolved that we should all go home.

Then came the packing up. Each had amassed a pile of specimens, well-nigh as large as himself, and it was of course impossible to carry everything away. A rapid selection had

therefore to be made. And oh! with how much reluctance were we compelled to relinquish many of the stones, the discovery whereof had made the opposite cavern ring again with our jubilee. Not one of us had had the foresight to provide himself with a bag, so we stowed away the treasures in our pockets. Surely practical geometry offers not a more perplexing problem than to gauge the capacity of these parts of a schoolboy's dress. So we loaded ourselves to the full, and marched along with the fossils crowded into every available corner.

Despite our loads, we left the quarry in high glee. Arranging ourselves instinctively into a concave phalanx, with the speaker in the centre, we resumed a tale of thrilling interest, that had come to its most tragic part just as we arrived at the quarry several hours before. It lasted all the way back, beguiling the tedium, darkness, and chill of the four miles that lay between the limeworks and our homes; and the final consummation of the story was artfully reached just as we came to the door of the first of the party who had to wish us good-night.

A Turning-point in Life

Such was my first geological excursion — a simple event enough, and yet the turning-point in a life. Thenceforward the rocks and their fossil treasures formed the chief subject of my every-day thoughts. That day stamped my fate, and I became a geologist.

And yet, I had carried home with me a strange medley of errors and misconceptions. Nearly every fossil we found was incorrectly named. We believed that we had discovered in the rock organisms which had really never been found fossil by living man. So far, therefore, the whole lesson had to be unlearned, and a hard process the unlearning proved to be. But (what was of infinitely more consequence at the time than the correct names, or even the true nature of the fossils) I had now seen fossils with my own eyes, and struck them out of the rock with my own hand. The meaning of the lessons we had been taught at school began to glimmer upon me; the dry bones of our books were touched into life; the idea of creations anterior to man seemed clear as a revealed truth; the fishes and plants of the lime quarry must have lived and died, but when and how? Was it possible for *me* to discover? . . .

I cannot recall the process of inquiry among my comrades. But I well remember how it went on with myself. Our early identifications of all that we saw in the rock with something we had seen in living nature were unconsciously abandoned. I gradually came to learn the true character of most of the fossils, and recognised, too, that there was much which I did not understand, but might fairly attempt to discover. The first love of rarities and curiosities passed away, and in its place there sprang up a settled belief that in these gray rocks there

lay a hidden story, if one could only get at the key.

There was no one within our circle of acquaintance from whom any practical instruction in the subject could be obtained. Probably this was a piece of good fortune for those of us who had the courage to persevere in the quest for knowledge. I can remember the long communings we had as to the nature of this or that organism, and its bearing on the history of the limestone. The text-books were of little service. So, thrown back upon ourselves, we allowed our fancy to supply what we could obtain in no other way. The ferns and other land-plants found in the limestone, together with the minute cyprids, of which the rock seemed in some places almost wholly composed, and the scales, bones, and teeth of ganoid fishes, indicated, as far as we could learn, that the deposit had accumulated in fresh water, perhaps in a lake or in the estuary of a river. But of course it was natural that we should try to discover what might have been the general aspect of the country when the animals and plants of the limestone were alive. We asked ourselves if the same hills existed then as now; if perchance the old river that swept over the site of the quarry took its rise among yonder pastoral glens; if the same sea rolled in the distance then as now, curling white along the same green shore. Happily ignorant of how far we had here ventured beyond our depth, it was not until after much

questioning and disappointment that I found these problems to require years of patient research. The whole country for many miles round had yet to be explored, and minute observations to be made before even an approximation to a reliable answer could be given. But a boy's fancy is an admirable substitute for the want of facts. I did feel at times a little sorry that no evidence turned up on which to ground my restoration of the ancient topography of the district, or rather that such a world of work seemed to rise before me ere I could obtain the evidence that was needed. But the feeling did not last long. And so I conjured up the most glorious pictures of an ancient world, where, as in the land of the lotus-eaters, it was always afternoon, and one could dream away life among isles clothed with ferns and huge club-mosses, and washed by lakes and rivers that lay without a ripple, save now and then when some glittering monster leapt out into the sunlight, and fell back again with a sullen plunge.

Happy afternoons were these! To steal away alone among the cornfields, and feast the eye on hill and valley, with their green slopes and bosky woods and gray feudal towers, and on the distant sea with the white sails speckled over its broad expanse of blue. And then when every part of that well-loved scene had been taken in, to let loose the fancy and allow the landscape to fade like a dissolving view until

every feature had fled, and there arose again the old vanished lakes, and rivers, and palmy isles.

Another Quarry

About two miles from the spot where we began our geological labours lay another quarry, from which lime had been extracted. When we first heard of it from a friend at the engine-house, we set it down as a continuation of his limework, the caverns of which seemed to run on underground to an indefinite length. There seemed nothing unlikely in the identification of two limestones only two miles distant from each other as part of one seam. So a Saturday afternoon was spent in the investigation of this second quarry.

Like the first, it had been opened along the slope of a gentle hill and the excavations presented to our view a long line of caverns similar to those we had seen before. But the quarry was disused, and appeared to have been so for many years. The roof had fallen down in many places, the mouths of the caves had become well-nigh choked up with rubbish and tangled gorse, and the heaps of debris, so fresh and clean in our own quarry, were here overgrown with gray lichens and green moss, damp and old. The kilns had not been fired for many a day. The cracks and rents that had fissured their walls, from the fierce heat that once blazed within, were yawning hideously, as if a strong

gale would hurl them with a crash into the half-buried cavern below. Only one human habitation was near, a small moss-grown cottage, where lived a little old woman, her skin brown and shrivelled as parchment, who was busy hanging out linen on a neighbouring hedge. Altogether, therefore, this second quarry had a very grave-like, antique look, and we entered it with a kind of boyish wonder whether so different a scene would yield us the same treasures as we had found so abundantly only two miles off.

It required but a cursory glance to show us that the two limestones were not the same. They differed in colour and texture, but still more in their fossil contents. We searched long but unsuccessfully for traces of the plants, of cyprids, or fish, so common at our first quarry. In their stead we hammered out an abundant series of quite different fossils, all new to us. Of course, in our attempts to discover the nature and habitats of these objects, we wandered as far from the truth as we had done before. After much blundering we eventually ascertained that the new treasures included corals, stone-lilies, and shells — all organisms of the sea-floor. But our most instructive collection of these relics of marine life were obtained from a much larger quarry some twelve miles away. This more distant locality was calculated to impress powerfully a much more matured imagination than that of boyhood. I have often since visited it, and always with fresh interest.

It has quiet, tree-shaded nooks, where, the din of the workmen being hushed by distance, one may sit alone and undisturbed for hours, gathering up from the grass-grown mounds delicate lamp-shells and sea-mats, crinoids, cup-corals, and many other denizens of the palæozoic ocean. A mass of rock, from which the rest has been quarried away, stands in a secluded coppice, overlooking the sea, as if to show how thick the seam was before the quarrymen began to remove it. This mass has been exposed to the weather for many a long year. Its steep sides are crowded with stone-lilies, corals, and shells, which stand out in relief like an arabesque fretwork. The marks of the quarrymen's tools have passed away, and a gray hue of age has spread over the rock, aided by patches of lichen and moss, or by tufts of fern, that here and there have found a nestling place. For here, as always where man has scarped and wounded the surface of the globe on which he dwells,

> Nature softening and concealing,
> Is busy with the hand of healing.

From this point, between the overhanging branches, our schoolboy band could watch the lights and shadows flitting athwart the distant hills, the breeze sweeping the neighbouring sea into fitful sheets of darker blue, and the sails for ever passing to and fro. And then, turning round, there rose behind us this strange wall of rock — the bottom of an older sea, with its

dead organisms piled by thousands over each other. I can never forget the impression made on my boyish mind by the realisation of this tremendous contrast in scenery and life, and of the vast gulf of time between the living world and the dead. It made a kind of epoch in one's life. My first afternoon in this old lime-quarry was of more service at this time than any number of books or lectures.

Love of Study Kindled

The recollection of these early days has often since impressed me with a sense of the enormous advantage which a boy or girl may derive from any pursuit that stimulates the imagination. My boyish geology was absurdly, grotesquely erroneous. I should have failed ignominiously at an examination which would be thought easy enough at a modern elementary science class. But I had gained for myself what these science classes so seldom infuse into the pupils — an enthusiastic love of the subject, and a determination to get somehow at the living truth of which the rocks are the records. I had learnt to treat fossils not as mere dead mineral matter, or as mere curiosities valuable in proportion to their rarity or perfection of preservation, but as enduring records of former life; not as species to fill a place in a zoölogical system, or specimens to take up so much room in a museum, but as the remains of once living organisms, which formed part of a creation as real as that in which

we ourselves pass our existence. They were witnesses of early ages in our planet's history, and were ready to tell their tale if one could only learn how to read it from them. Few occupations possess greater power of fascination than to marshal all these witnesses, and elicit from them the evidence which allows us to restore one after another the successive conditions through which the solid land has passed. To realise how this is done, and to take part in the doing of it, is for a boy a lifelong advantage. He may never become a geologist in any sense, but he gains such an enlarged view of nature, and such a vivid conception of the long evolution through which the present condition of things has been reached, as can be mastered in no other way. A single excursion under sympathetic and intelligent guidance to an instructive quarry, river ravine, or sea-shore, is worth many books and a long course of systematic lectures.

JAMES NASMYTH

[James Nasmyth, inventor of the steam hammer and other machines of prime importance, was born in Edinburgh, August 19, 1808. His father, Alexander Nasmyth, was a distinguished painter of portraits and landscapes, whose talents descended, in a marked degree, to his son. James Nasmyth is one of the group of which Leonardo Da Vinci was the unapproached chieftain — whose genius as engineers owed much to the observant eye, the deft hand, the embodying imagination, of the trained artist. Nasmyth was so successful an inventor and manufacturer that he retired from business with a competency at forty-eight years of age. As a recreation he betook himself to astronomy and studied the sun and moon with results which earned commendation from Sir John Herschel. He died in London in his eighty-second year.

The pages which follow are taken from his Autobiography, edited by Samuel Smiles, and published with a portrait by John Murray, London, 1883. — ED.]

INTEREST IN WORKSHOPS AS A BOY

WHILE enjoying delightful holidays, before my school-days began, my practical education was in progress, especially in the way of acquaintance with the habits of nature in a vast variety of its phases, always so attractive to the minds of healthy children. It happened that close to the Calton Hill, Edinburgh, in the valley at its northern side, there were many workshops where interesting trades were carried on, such as those of coppersmiths, tinsmiths, brass-founders, goldbeaters, and blacksmiths. Their

shops were all gathered together in a busy group at the foot of the hill, in a place called Greenside. The workshops were open to the inspection of passers by. Little boys looked in and saw the men at work amidst the blaze of fires and the beatings of hammers.

Amongst others, I was an ardent admirer. I may almost say that this row of busy workshops was my first school of practical education. I observed the mechanical manipulation of the men, their dexterous use of the hammer, the chisel, and the file; and I imbibed many lessons which proved of use to me in my later years. Then I had tools at home in my father's workshop. I tried to follow their methods; I became greatly interested in the use of tools and their appliances; I could make things for myself. In short, I became so skilled that the people about the house called me "a little Jack-of-all-trades."

Delight in the Company of Artists

Henry Raeburn, the famous portrait painter, often joined my father in his afternoon walks round Edinburgh — a relaxation so very desirable after hours of close attention to artistic work. They took delight in the wonderful variety of picturesque scenery by which the city is surrounded. The walks about Arthur's Seat were the most enjoyable of all. When a boy I had often the pleasure of accompanying them, and of listening to their conversation.

I thus picked up many an idea that served me well in after life. Indeed, I may say, after a long experience, that there is no class of men whose company I more delight in than that of artists. Their innate and highly cultivated power of observation, not only as regards the ever-varying aspects of nature, but also as regards the quaint, droll, and humorous varieties of character, concur in rendering their conversation most delightful. I look back on these events as among the brightest points in my existence. I have been led to digress on this subject. Although more correctly belonging to my father's life, yet it is so amalgamated with my own that it almost forms part of it, and it is difficult for me to separate the one from the other.

And then there were the pleasant evenings at home. When the day's work was over friends looked in to have a fireside chat — sometimes scientific men, sometimes artists, often both. They were all made welcome. There was no formality about their visits. Had they been formal, there would have been comparatively little pleasure. The visitor came in with his "Good e'en," and seated himself. The family went on with their work as before. The girls were usually busy with the needles, and others with pen and pencil. My father would go on with the artistic work he had in hand, for his industry was incessant. He would model a castle or a tree, or proceed with

some proposed improvement of the streets or approaches of the rapidly expanding city.

Collects Old Coins

Like many earnest-minded boys, I had a severe attack at the right time of life, say from twelve to fifteen, of what I would call "the collecting period." This consisted, in my case, of accumulating old coins, perhaps one of the most salutary forms of this youthful passion. I made exchanges with my school companions. Sometimes my father's friends, seeing my anxiety to improve my collection, gave me choice specimens of bronze and other coins of the Roman emperors, usually duplicates from their own collection. These coins had the effect of promoting my knowledge of Roman history. I read up in order to find out the acts and deeds of the old rulers of the civilised world. Besides collecting the coins, I used to make careful drawings of the obverse and reverse faces of each in an illustrated catalogue which I kept in my little coin cabinet.

I remember one day, when sitting beside my father, making a very careful drawing of a fine bronze coin of Augustus, that Sir Walter Scott entered the room. He frequently called upon my father in order to consult him with respect to his architectural arrangements. Sir Walter caught sight of me, and came forward to look over the work I was engaged in. At his request I had the pleasure of showing him my little

store of coin treasures, after which he took out of his waistcoat pocket a beautiful silver coin of the reign of Mary Queen of Scots, and gave it to me as being his "young brother antiquarian." I shall never forget the kind fatherly way in which he presented it. I considered it a great honour to be spoken to in so friendly a way by such a man; besides, it vastly enriched my little collection of coins and medals.

Begins to Use a Lathe

While attending the High School, from 1817 to 1820, there was the usual rage amongst boys for spinning-tops and "young cannon." By means of my father's excellent foot-lathe I turned out the spinning-tops in capital style, so much so that I became quite noted amongst my school companions. They all wanted to have specimens of my productions. They would give any price for them. The tops were turned with perfect accuracy, and the steel spinning pivot, was centred so as to correspond with the heaviest diameter at the head. They could spin twice as long as the bought tops. When at full speed they would "sleep," that is, turn round without a particle of waving. This was considered high art as regarded top-spinning.

Flying-kites and tissue paper balloons were articles that I was somewhat famed for producing. There was a good deal of special skill required for the production of a flying-kite.

It must be perfectly still and steady when at its highest flight in the air. Paper messengers were sent up to it along the string which held it to the ground. The top of the Calton Hill was the most favourite place for enjoying this pleasant amusement.

Another article for which I became equally famous was the manufacture of small brass cannon. These I cast and bored, and mounted on their appropriate gun-carriages. They proved very effective, especially in the loudness of the report when fired. I also converted large cellar-keys into a sort of hand-cannon. A touch-hole was bored into the barrel of the key, with a sliding brass collar that allowed the key-guns to be loaded and primed and ready for firing.

Learned More in Workshops than at School

I did not learn much at the High School which I attended. My mind was never opened up by what was taught me there. It was a mere matter of rote and cram. I learnt by heart a number of Latin rules and phrases, but what I learnt soon slipped from my memory. My young mind was tormented by the tasks set before me. At the same time my hungry mind thirsted for knowledge of another kind.

There was one thing, however, that I *did* learn at the High School. That was the blessings and advantages of friendship. There were several of my schoolfellows of a like disposition

with myself, with whom I formed attachments which ended only with life. I may mention two of them in particular — Jemmy Patterson and Tom Smith. The former was the son of one of the largest iron founders in Edinburgh. He was kind, good, and intelligent. He and I were great cronies. He took me to his father's workshops. Nothing could have been more agreeable to my tastes. For there I saw how iron castings were made. Mill-work and steam-engines were repaired there, and I could see the way in which power was produced and communicated. To me it was a most instructive school of practical mechanics. Although I was only about thirteen at the time, I used to lend a hand, in which hearty zeal made up for want of strength. I look back to these days, especially to the Saturday afternoons spent in the workshops of this admirably conducted iron foundry, as a most important part of my education as a mechanical engineer. I did not read about such things; for words were of little use. But I saw and handled, and thus all the ideas in connection with them became permanently rooted in my mind.

Learns how to Harden and Temper Steel

To Johnnie Syme, foreman in Mr. Patterson's iron-foundry, I owe a special debt of gratitude, as it was he who first initiated me into that most important of all technical processes in practical mechanism — the art of hardening and tempering

steel. It is, perhaps, not saying too much to assert that the successful practice of the mechanical arts, by means of which the civilised man rises above the savage condition, is due to that wonderful change. Man began with wood, and stone, and bone; he proceeded to bronze and iron; but it was only by means of hardened steel that he could accomplish anything in arms, in agriculture, or in architecture. The instant hardening which occurs on plunging a red-hot piece of steel into cold water may well be described as mysterious. Even in these days, when science has defined the causes of so many phenomena, the reason of steel becoming hard on suddenly cooling it down from a red heat is a fact that no one has yet explained! The steel may be tempered by modifying the degrees of heat to which it is subsequently subjected. It may thus be toughened by slightly reheating the hardened steel; the resoftening course is indicated by certain prismatic tints, which appear in a peculiar mode of succession on its surface. The skilful artisan knows by experience the exact point at which it is necessary again to plunge it into cold water in order to realise the requisite toughness or hardness of the material required for his purposes.

Is Taught Drawing as a Graphic Language

Besides visiting and taking part in the works at Patterson's foundry, and joining in the chemical experiments at Smith's laboratory,

my father gave me every opportunity for practising the art of drawing. He taught me to sketch with exactness every object, whether natural or artificial, so as to enable the hand to accurately reproduce what the eye had seen. In order to acquire this almost invaluable art, which can serve so many valuable purposes in life, he was careful to educate my eye, so that I might perceive the relative proportions of the objects placed before me. He would throw down at random a number of bricks, or pieces of wood representing them, and set me to copy their forms, their proportions, their lights and shadows respectively. I have often heard him say that any one who could make a correct drawing in regard to outline, and also indicate by a few effective touches the variation of lights and shadows of such a group of model objects, might not despair of making a good and correct sketch of the exterior of York Minster.

My father was an enthusiast in praise of this graphic language and I have followed his example. In fact, it formed a principal part of my own education. It gave me the power of recording observations with a few graphic strokes of the pencil; and far surpassed in expression any number of mere words. This graphic eloquence is one of the highest gifts in conveying clear and correct ideas as to the forms of objects — whether they be those of a simple and familiar kind, or of some form of mechanical construction, or of the details of

a fine building, or the characteristic features of a wide-stretching landscape. This accomplishment of accurate drawing, which I achieved for the most part in my father's workroom, served me many a good turn in future years with reference to the engineering work which became the business of my life.

Makes Chemicals for Himself

My friend Tom Smith and I made it a rule — and in this we were encouraged by his father — that, so far as was possible, we ourselves should actually make the acids and other substances used in our experiments. We were not to buy them ready made, as this would have taken the zest out of our enjoyment. We should have lost the pleasure and instruction of producing them by means of our own wits and energies. To encounter and overcome a difficulty is the most interesting of all things. Hence, though often baffled, we eventually produced perfect specimens of nitrous, nitric, and muriatic acids. We distilled alcohol from duly fermented sugar and water, and rectified the resultant spirit from fusel oil by passing the alcoholic vapour through animal charcoal before it entered the worm of the still. We converted part of the alcohol into sulphuric ether. We produced phosphorus from old bones, and elaborated many of the mysteries of chemistry.

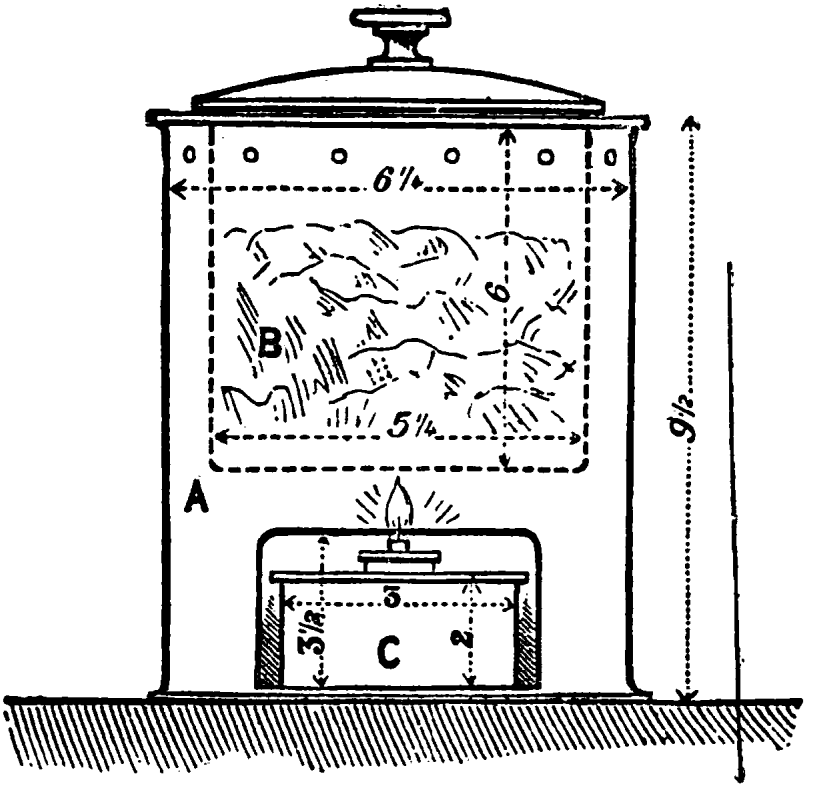
The amount of practical information which we obtained by this system of making our own

chemical agents was such as to reward us, in many respects, for the labour we underwent. To outsiders it might appear a very troublesome and roundabout way of getting at the finally desired result. But I feel certain that there is no better method of rooting chemical, or any other instruction, deeply in our minds. Indeed, I regret that the same system is not pursued by the youth of the present day. They are seldom, if ever, called upon to exert their own wits and industry to obtain the requisites for their instruction. A great deal is now said about technical education; but how little there is of technical handiness or head work! Everything is bought ready made to their hands; and hence there is no call for individual ingenuity.

Invents a Cooking Apparatus

On the 30th of May, 1829, I commenced my regular attendance at Mr. Henry Maudsley's famous workshop in London. My first job was to assist him in making some modifications in the details of a machine which he had contrived some years before for generating original screws. . . . This beautiful contrivance became, in the hands of its inventor, the parent of a vast progeny of perfect screws, whose descendants are to be found in every workshop throughout the world, where first class machinery is constructed. The production of perfect screws was one of Maudsley's highest ambitions and his principal achievement.

My wages at first were but ten shillings ($2.43) a week, and I was resolved that they should maintain me in food and lodging. I therefore directed my attention to economical living. I found that a moderate dinner at an eating-house would cost more than I could afford. In order to keep within my weekly



income I bought the raw materials and cooked them in my own way and to my own taste. I set to and made a drawing of a very simple, compact, and handy cooking apparatus. I took the drawing to a tinsmith near at hand, and in two days I had it in full operation. The apparatus cost ten shillings, including the lamp. As it contributed in no small degree to enable me to carry out my resolution, and as it may

serve as a lesson to others who have an earnest desire to live economically, I think it may be useful to give a drawing and a description of my cooking stove.

The cooking or meat pan rested on the upper rim of the external cylindrical case, and was readily removable in order to be handy for service. The requisite heat was supplied by an oil lamp with three small wicks. I put the meat in the pot, with the other comestibles, at nine o'clock in the morning. It simmered away all day, until half past six in the evening, when I came home with a healthy appetite to enjoy my dinner.

The meat I generally cooked was leg of beef with sliced potato, bits of chopped onion, and a modicum of pepper and salt, with just water enough to cover the whole completely. When stewed slowly the meat became very tender, yielding a capital dish. It was partaken of with a zest that, no doubt, was a very important element in its savouriness. The whole cost of this capital meal was fourpence halfpenny (nine cents). I sometimes varied the meat with rice boiled with milk and a pennyworth of raisins. My breakfast and tea, with bread, cost me about fourpence (eight cents) each. My lodgings cost three shillings and six pence (eighty-five cents) a week. A little multiplication will satisfy any one that I contrived to live economically and comfortably on my ten shillings a week. In the following year my

wages were raised to fifteen shillings a week, and then I began to take butter to my bread.

Handiness of the Old-time Mechanic

During my early life the skilful workmen employed in the engineering establishments of Scotland (which were then comparatively small in size) were accustomed to use all manner of mechanical tools. They could handle with equally good effect the saw, the plane, the file, and the chisel, and, as occasion required, they could exhibit their skill at the smith's forge with the hammer and the anvil. This was the kind of workmen with which I had reinforced the foundry. The men had been bred to various branches of mechanics. Some had been blacksmiths, others carpenters, stone masons, brass or iron founders; but all of them were handy men. They merely adopted the occupation of machine and steam-engine makers because it offered a wider field for the exercise of their skill and energy.

I may here be allowed to remark that we owe the greatest advances in mechanical invention to Free Trade in Ability. If we look carefully into the narratives of the lives of the most remarkable engineers, we shall find that they owed very little to the seven years' rut in which they were trained. They owed everything to innate industry, energy, skill, and opportunity. Thus, Brindley advanced from the position of a millwright to that of a canal engineer; Smeaton

and Watt, from being mechanical instrument makers, advanced to higher positions — the one to be the inventor of the modern lighthouse, the other to be the inventor of the condensing steam-engine. Some of the most celebrated mechanical and civil engineers — such as Rennie, Cubitt, and Fairbairn — were originally millwrights. All these men were many-handed. They had many sides to their intellect. They were resourceful men. They afford the best illustrations of the result of Free Trade in Ability.

Invents the Steam Hammer

[In 1836 Nasmyth, in partnership with Holbrook Gaskell, established the Bridgewater Foundry at Patricroft, near Manchester. One of the best customers of the firm was the Great Western Company which built the famous steamship, the *Great Western*, which plied between Bristol and New York. So successful was this steamer that the Company ordered the construction of a much larger vessel, the *Great Britain*.]

An unexpected difficulty, however, was encountered with respect to the enormous wrought-iron intermediate paddle-shaft. It was required to be of a size and diameter the like of which had never been forged. Mr. Humphries applied to the largest firms throughout the country for tenders of the price at which they would execute this important part of the work, but to his surprise and dismay he found that not one of them would undertake so large a forging. In this dilemma he wrote a letter to me, which I received on the 24th of

November, 1839, informing me of the unlooked-for difficulty. "I find," he said, "that there is not a forge hammer in England or Scotland powerful enough to forge the intermediate paddle-shaft of the engines for the *Great Britain!* What am I to do? Do you think I might dare to use cast-iron?"

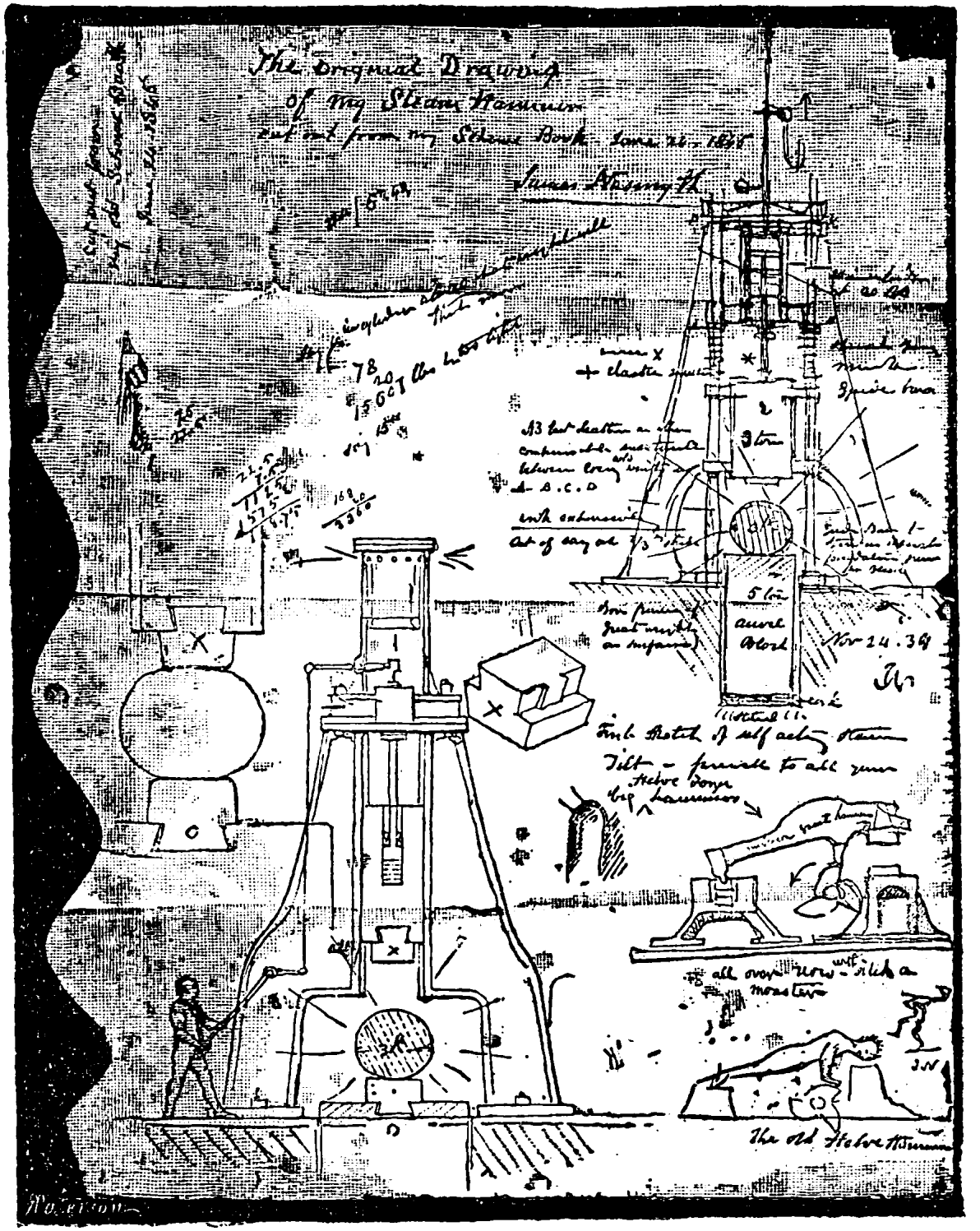
This letter immediately set me a-thinking. How was it that the existing hammers were incapable of forging a wrought-iron shaft of thirty inches diameter? Simply because of their want of compass, of range and fall, as well as of their want of power of blow. A few moments' rapid thought satisfied me that it was by our rigidly adhering to the old traditional form of a smith's hand hammer — of which the forge and tilt hammer, although driven by water or steam power, were mere enlarged modifications — that the difficulty had arisen; as, whenever the largest forge hammer was tilted up to its full height, its range was so small that when a piece of work of considerable size was placed on the anvil, the hammer became "gagged"; so that, when the forging required the most powerful blow, it received next to no blow at all, as the clear space for the fall of the hammer was almost entirely occupied by the work on the anvil.

The obvious remedy was to contrive some method by which a ponderous block of iron should be lifted to a sufficient height above the object on which it was desired to strike a blow, and then to let the block full down upon the

forging, guiding it in its descent by such simple means as should give the required precision in the percussive action of the falling mass. Following up this idea, I got out my "Scheme Book," on the pages of which I generally thought out, with the aid of pen and pencil, such mechanical adaptations as I had conceived in my mind, and was thereby enabled to render them visible. I then rapidly sketched out my steam hammer, having it all clearly before me in my mind's eye. In little more than half an hour I had the whole contrivance, in all its details, before me on a page, a reduced copy of which is appended to this description. The date of this first drawing was the 24th of November, 1839.

My steam hammer, as thus first sketched, consisted of, first, a massive anvil on which to rest the work; second, a block of iron constituting the hammer itself; and, third, an inverted steam cylinder to whose piston-rod the hammer-block was attached. All that was required was to admit steam of sufficient pressure into the cylinder, so as to act on the under-side of the piston, and thus raise the hammer-block attached to the end of the piston-rod. By a very simple arrangement of a slide valve, under the control of an attendant, the steam was allowed to escape and thus permit the massive block of iron to descend by its own gravity upon the work then upon the anvil.

Thus by the more or less rapid manner in


The Original Drawing
of my Steam Hammer
cut out from my Sketch Book June 21. 1841
James Nasmyth
The old Helve Hammer

which the attendant allowed the steam to enter or escape from the cylinder, any required number or intensity of blows could be delivered. Their succession might be modified in an instant. The workman might thus, as it were, think in blows. He might deal them out on to the ponderous glowing mass, and mould or knead it as if it were a lump of clay; or, if he pleased, pat it with gentle taps.

Anchors Forged by the Steam Hammer

One of the most important uses of the steam hammer was in forging anchors. Under the old system anchors — upon the soundness of which the safety of ships so often depends — were forged upon the "bit by bit" system. The various pieces of an anchor were welded together, but at the parts where the different pieces of iron were welded together, flaws often occurred; the parts would break off — blades from the stock, or flukes from the blades — and leave the vessel, which relied upon the security of its anchor, to the risk of the winds and the waves. By means of the steam hammer these risks were averted. The slag was driven out during the hammering process. The anchor was sound throughout because it was welded as a whole.

Those who are technically acquainted with smith work as it used to be practised, by what I term "the bit by bit" system — that is, of building up from many separate parts of iron, afterward welded together into the required

form — can appreciate the vast practical value of the die method brought into general use by the controllable but immense power of the steam hammer. At a very early period of my employment of the steam hammer, I introduced the system of stamping masses of welding hot iron as if it had been clay, and forcing it into suitable moulds or dies placed upon the anvil. This practice had been in use on a small scale in the Birmingham gun trade. The ironwork of fire-arms was thus stamped into exact form. But, until we possessed the wide range and perfectly controllable powers of the steam hammer, the stamping system was confined to comparatively small portions of forge work. The new power enabled the die and stamp system to be applied to the largest class of forge work; and another era in the working of ponderous masses of smith and forge work commenced, and has rapidly extended until the present time. Without entering into further details, the steam hammer, has advanced the mechanical arts, especially with relation to machinery of the larger class, to an extent that is of incalculable importance.

His Aims as an Inventor

In mechanical structures and contrivances, I have always endeavoured to attain the desired purpose by the employment of the fewest parts, casting aside every detail not absolutely necessary, and guarding carefully against the intrusion of mere traditional forms and arrange-

ments. The latter are apt to insinuate themselves, and to interfere with that simplicity and directness of action which is in all cases so desirable a quality in mechanical structures. Plain common sense should be apparent in the general design, as in the form and arrangement of the details; and a general character of severe utility pervade the whole, accompanied with as much attention to gracefulness of form as is consistent with the nature and purpose of the structure.

Faults in Modern Architecture

[Let the parting word of Nasmyth be spoken by him as a critic of art, which, by virtue of early training, he continued to be throughout his life.]

It appears to me that one of the chief causes of the inferiority and defects of modern architecture is that our designers are so anxious to display their taste in ornamentation. They first design the exterior, and then fit the interiors of their buildings into it. The purpose of the building is thus regarded as a secondary consideration. In short, they utilise ornament instead of ornamenting utility — a total inversion, as it appears to me, of the fundamental principle which ought to govern all classes of architectural structures. This is, unfortunately, too evident in most of our public buildings.

One thing I was especially struck with at Nismes in France — the ease with which some thousands of people might issue, without

hindrance, from the Amphitheatre. The wedge-shaped passages radiate from the centre, and, widening outwards, would facilitate the egress of an immense crowd. Contrast this with the difficulty of getting out of any modern theatre or church in case of alarm or fire. Another thing is remarkable — the care with which the huge blocks of dolomite have been selected. Some of the stone slabs are eighteen feet long; they roof over the corridors; yet they still retain the marks of the Roman chisel. Every individual chip is as crisp as on the day on which it was made; even the delicate "scribe" marks, by which the mason, some 1900 years ago, lined out his work on the blocks of stone he was about to chip into its required form, are still perfectly distinct.

SIR HENRY BESSEMER

[Sir Henry Bessemer, of London, in 1855 invented his famous process for cheaply converting pig-iron into malleable iron and steel. How he arrived at that process and brought it to perfection is told in his Autobiography, published by *Engineering*, 36 Bedford Street, Strand, London. By permission of the publishers that work has been drawn upon for the pages which follow, reciting the story of his first success as an inventor. The Autobiography, handsomely illustrated, is one of the most interesting books of its kind ever written. — ED.]

BEGINS TURNING AND MODELLING

AFTER leaving school I begged my father to let me remain at home, and learn something from him of practical engineering. This he acceded to, and as a preliminary step he bought me a beautiful, small slide-rest lathe. After a year or two at the vice and lathe, and other practical mechanical work, my father allowed me to employ myself in making working models of any of the too-numerous schemes which the vivid imagination of youth suggested. Among these, I well remember, was a machine for making bricks, producing pretty little model bricks in white pipeclay. I always had access to molten type-metal, which I used for casting wheels, pulleys, and other parts of mechanical models where strength was not much required. Hence arose various devices for moulding different forms, a matter that caused me very

little trouble, for by some intuitive instinct modeling came to me unsought and unstudied.

In our quiet village life, at Charlton in Hertfordshire, there was a break every two months, when the large melting furnace was used to make type-metal, in which proceeding a great secret was involved. In spite of injunctions to the contrary I would, by some means or other, find my way into the melting-house, where large masses of antimony were broken to form the alloy with lead. I soon discovered that the addition of tin and copper, in small quantities, to the ordinary alloy, was the secret by which my father's type lasted so much longer than that produced by other type-founders.

[In 1831 Bessemer removed from Charlton to London. There he entered upon his career as a successful inventor, devising machinery for stamping velvet, for cancelling revenue stamps, and for composing type. His next, and decisive, step is thus narrated.]

Manufacture of Bronze Powder

My eldest sister was a clever painter in water colours, and in her early life, in the village of Charlton, she had ample opportunities for indulging her taste for flower-painting. She had accumulated a charming collection of tulips, chrysanthemums, and other blossoms, and had, with much ingenuity made a portfolio for their reception. She wished to have the words: "Studies of Flowers from Nature, by

Miss Bessemer," written in bold printing letters within a wreath of acorns and oak leaves which she had painted on the outside of the portfolio. As I was somewhat of an expert in writing ornamental characters, she asked me to do this for her.

How trivial this incident may appear to my readers! It was, nevertheless, fraught with the most momentous consequences to me; in fact, it changed the whole current of my life, and rendered possible that still greater change which the iron and steel industry of the world has undergone.

The portfolio was so prettily finished that I did not like to write the desired inscription in common ink; and as I had once seen some gold powder used by japanners, it struck me that this would be appropriate for the lettering I had undertaken. How distinctly I remember going into a shop in Clerkenwell to buy this "gold powder," or, to use its trade name, "bronze powder." I was shown samples of two colours, and bought an ounce of each, at the astonishing price of seven shillings ($1.70) per ounce. On my way home I could not help asking myself, "How can this simple metallic powder cost so much?" Even at seven shillings an ounce there could not have been gold enough in it to give the powder its beautiful rich colour. I believed it to be, probably, only a better sort of brass; and for brass in any conceivable form this was a marvellous price.

I hurried home, and submitted a portion of both samples to the action of dilute sulphuric acid, and satisfied myself that no gold was present. I still remember with what impatience I watched the solution of the powder, and how forcibly I was struck with the immense advantage it offered as a manufacture, if skilled labour could be superseded by steam power. Here was powdered brass selling retail at 112 shillings ($27.25) per pound, while the raw material from which it was made probably cost no more than sixpence (12 cents). "It must surely," I thought, "be made slowly and laboriously by some old-fashioned hand process; and if so, it offers a splendid opportunity for any mechanic who can devise a machine capable of producing it simply by steam power."

I plunged headlong into the problem. At first, I endeavoured to ascertain how the powder was made, but no one could tell me. At last I found that it was made chiefly at Nuremberg, and that its mode of manufacture was kept a profound secret. I hunted up many old books, and in one of them I found a description of the powder as being made of various copper alloys beaten into thin leaves, after the manner of making gold leaf, in books of parchment and gold-beater's skin. The delicate thin leaves so made were ground by hand labour to powder on a marble slab with a stone muller, and mixed with a thick solution of gum arabic to form a stiff paste and facilitate the grinding process.

The gum so added was afterward removed by successive washings in hot water. It thus became evident that the great cost of bronze powder was due to this slow and most expensive mode of manufacture, and it was equally clear that if I could devise some means of producing it from a solid lump of brass, by steam power, the profits would be very considerable. With these convictions I at once set to work. I had at that time a two-horse-power engine, partly made by myself, which I finished and erected in a small private room at the back of my house, where I could make my experiments in secret.

Then came the all-important question, from what point was I to attack the problem? An attempt to imitate the old process by any sort of automatic mechanism seemed to present insurmountable obstacles — the thousands of delicate skins to be manipulated, the fragile leaves of metal that would be carried away by the smallest current of air from a revolving drum or a strap in motion, and the large amount of power which must of necessity be employed to reduce the metal in whatever way it was treated. This necessity for delicate handling gave a negative to any hope of producing the powder in a way analogous to the one in use.

How could I then proceed? A mass of solid brass did not appear to be a likely thing to fall to powder under treatment by a pestle and mortar. Then came the question: Can the metal be rendered brittle, and so facilitate its

reduction? No, it cannot be made brittle except by alloying it with such other metals as will destroy its beautiful gold colour. Then there was the question of the solution of the metal in acid, and its precipitation as powder. These and many other plans were thought of, only to be put aside as impracticable.

The First Machine

The first idea which presented itself to my mind as a possible mode of reducing a piece of hard, tough brass to extremely minute, brilliant particles was based on the principles of the common turning lathe, with which I made my first attempt on a circular disc of brass. This was mounted on a suitable mandrel, and revolved 200 times per minute. The revolving brass disc was tightly pressed between two small steel rollers, having fine but very sharp diagonal grooves on their surfaces, sloping to the left on one of them, and to the right on the other; the effect of this was to impress diagonal lines crossing each other on the periphery of the brass disc and to form on it a series of minute squares. If the reader examines the milled edge of a gold coin, he will see just such indented lines running across its rim, but on my brass disc the lines were V-shaped. A flat-faced turning tool mounted on a slide-rest was slowly advanced in the direction of the disc, so as to shave off an extremely thin film of metal from the apex of every one of the truncated pyramids

formed on the periphery of the disc. With a disc whose periphery had a surface of four square inches, I estimated that I could cut off eight million small particles of brass per minute, all exactly alike in form and size, the continued pressure of the steel rollers renewing the depth of the grooves as fast as the cutter pared them down.

From this it will be obvious that in a machine closely resembling a lathe, discs much larger than my experimental disc could be treated; and that ten or a dozen such discs could be put at small distances apart on the same mandrel. In this way a large quantity of solid brass could be quickly made into powder. It will also be understood that the cutter could be advanced so slowly by a fine screw properly geared that a mere film of brass would be taken off the summit of each pyramid, producing a very fine powder.

Such was the theory on which I relied in my first attempt to produce a bronze powder from solid brass. My experimental apparatus was made very accurately in all its working parts, and it was with anxiety that I awaited the time necessary to get the first results of this novel scheme, which I may say at once were very unsatisfactory. It is true that the machine worked admirably, and minute particles of brass were produced and thrown up like a little fountain of yellow dust as the machine spun round; but, alas! neither to the touch nor to the

eye did it resemble the bronze powder of commerce. I was, I may frankly own, deeply disappointed at this failure. Fortunately, my sanguine temperament soon enabled me to forget my ill fortune, and again to pursue quietly my usual avocations.

A Fresh Start

About a year after this, I happened to be talking to the elder Mr. De La Rue, when he mentioned to me a matter in which he was greatly interested. He was justly irritated with a merchant who sold him arrowroot largely adulterated with potato starch, which had spoiled a considerable amount of valuable work, for which the pure starch of arrowroot was required. He had, he said, just found a mode of ascertaining accurately the percentage of potato starch present; he added that chemically these substances were so much alike in their constituents that he could not rely on simple analysis as a proof of fraud. He told me that by putting, say, 100 granules of the adulterated starch, as powder, under the microscope, he could see that there were present granules of two distinct shapes. The genuine arrowroot consisted of oval granules, while the potato-starch granules were perfectly spherical; and by simply counting the number of each shape in any given quantity he could ascertain beyond question the percentage of adulteration.

I was a good deal struck by this ingenious

mode of detection; and a few days later, when thinking it over, it occurred to me that possibly the microscope might throw some light on the cause of the failure of my attempts to produce bronze powder. I submitted some of the brass powder I had made and some of the ordinary powder of commerce to microscopic examination, and saw in a moment the cause of my failure. The ordinary bronze powder is made from an exceedingly thin leaf of beaten metal, resembling an ordinary leaf of gold. Now, such a thin flake, rubbed or torn to fragments, will, on a smaller scale, resemble a sheet of paper torn into minute pieces; and if such fragments of paper were allowed to fall on a varnished or adhesive surface, they would not stand up on edge, but would lie flat down, and when pressed open would represent a continuous surface of white paper. So it was with the bronze powder of commerce; when applied to an adhesive surface, the small flat fragments of leaf (for such they are) present a continuous bright surface and reflect light as from a polished metal plate. But the particles of metal made from my machine, minute as they were, presented a quite different appearance. Under a high magnifying power they were found to be little curled-up pieces one side being bright and the other rough and corrugated, and destitute of any brilliancy; while on being applied to an adhesive surface they arranged themselves, without order, like grains of sand or other amorphous bodies, and

reflected scarcely any light to the eye. The reason of my failure was now perfectly obvious.

This critical examination, and the evidence it afforded me of what was really necessary to constitute bronze powder, began to excite my imagination; for to make a pound of brass in an hour, by machinery, equal in value to an ounce of gold, was too seductive a problem to be easily relinquished. Again the idea and the hope of its realisation took possession of me. "Was this to be, after all," I asked myself, "the one great success I had so long hoped for, which was to wipe away all my other pursuits in life, and land me in the lap of luxury, if not absolute wealth?"

I studied the whole question over and over again, from every point of view, and week after week I became more certain that I was on the right track. At length I came to an absolute decision. "Yes," I said, "I will throw myself into it again "

Success at Last

I then went systematically to work, and drew out the detailed plans for the different machines that were necessary to test my idea thoroughly. I bought a four horse-power steam engine and erected it in close connection with my dwelling house. I made part of the machinery in my own workshops, and personally erected the whole of it in a room which nobody entered but myself. At last, after months of labour, the great day of

trial once more arrived, and I had to submit the raw material to the inexorable test. I watched the operations with a beating heart, and saw the iron monster do its appointed work, not to perfection, but so far well as to constitute an actual commercial success. I felt that on the result of that hour's trial hung the whole future of my life's history, and so it did, as the sequel will clearly show.

. . . . Before long my bronze powder, much improved in quality, was fully recognized in the trade, and found its way into every state in Europe and America; it had, in fact, become the one staple manufacture I had so long and so earnestly sought for, and which I hoped would one day replace and render unnecessary the constantly recurring small additions to the business I had so laboriously built up. The bronze powder manufacture, secretly conducted on a large scale without a patent, was soon so well managed by the staff I had chosen that it no longer required my personal attention. The large profits derived from it not only furnished me with the means of obtaining all reasonable pleasures and social enjoyments, but, what was even a greater boon in my particular case, they provided the funds demanded by the ceaseless activity of my inventive faculties, without my ever having to call in the assistance of the capitalist in patenting and experimenting on my too numerous inventions.

THOMAS ALVA EDISON

[This man of genius, who created the phonograph, was born in Milan, Ohio, February 11, 1847. Until the nineteenth century the chief servant of mankind was Fire. Thanks to investigators of whom Faraday was the chief, and to inventors of the stamp of Edison, Electricity is now doing all that fire ever did, doing it better, and performing, besides, a thousand tasks impossible to flame. Edison has enriched electric telegraphy with the quadruplex and other instruments of marvellous ingenuity, he has invented dynamos of high merit; he was a pioneer of electric traction; he has done more than any one else for the success of electricity as light. On March 5, 1904, the *Electrical World and Engineer*, of New York, gave his account of the beginnings of his incandescent lamp. By his consent, and that of the McGraw Publishing Company, the article is here reprinted. — ED.]

BEGINNINGS OF THE INCANDESCENT LAMP

FIRST EXPERIMENTS

MY EXPERIMENTS on carbon began in 1876, when I had the idea of making carbon wire, etc., for various electrical and chemical purposes. Even at that early time Messrs. Charles Batchelor and E. H. Johnson were with me, and we saw quite a business ahead in carbon novelties. I had familiarised myself with the properties of carbon, particularly that made from paper and Bristol board, and this led on very naturally to my work on the carbon telephone or microphonic transmitter, early in 1877. In the fall of that year I was pretty well through with studies and

inventions in that line, but had several other ideas that I wanted to work up. One of these was the subdivision of the electric light, and I began experimenting with that purpose. My records and the voluminous testimony in litigation, now happily long past, show that in the fall of 1877, about September, strips of carbonised paper were tried as an incandescent conductor suitable for use in lamps, and the work was followed up until January of 1878, when the general excitement over my invention and exhibition of the phonograph out at old Menlo Park frustrated serious or continuous work for a time in any other direction. In fact, my health gave way under the strain, and in July I broke away for a western trip as far as California.

PAPER CARBONS

Of course my mind was turning the subject over, and when I got back in August we immediately went at it again. Around October and November Batchelor made a great number of paper carbons, at least fifty, from tissue and other kinds of paper, coated over their surface with mixture of lampblack and tar, rolled them up into the fine long form of a knitting needle, and then carbonised them. These we put into circuit and brought up to incandescence in vacuo, although they would last but an hour or two. We tried a great many experiments with paper carbons, wood carbons, and some made from

carbonised broom corn. What we desired at that date, and had settled our minds upon as the only possible solution of the subdivision of the electric light, was that the lamps must have high resistance and small radiating surface. About December, 1878, I engaged as mathematician Mr. Francis R. Upton, who had lately studied under Helmholtz in Germany, and he helped me greatly in calculations of the multiple arc problem. Our figure proved that the lamp must have at least 100 ohms resistance to compete successfully with gas, for if the lamps were of the low resistance, the cost of the copper main conductors would be so great as to render the system uneconomical and commercially impracticable. In this direction we tried platinum also; and when working on incandescent platinum we had procured a Sprengel mercury pump and had ascertained that we could thus get exceedingly high vacua.

VACUOUS BULBS PERFECTED

It occurred to me that perhaps a "filament" of carbon could be made to stand in the sealed glass vessels or bulbs, which we were using, exhausted to a high vacuum. Separate lamps were made in this way independent of the air pump, and in October, 1879, we made lamps of paper carbon, and with carbons of common sewing thread, placed in a receiver or bulb made entirely of glass, with the leading in wires sealed

in by fusion. The whole thing was exhausted by the Sprengel pump to nearly one-millionth of an atmosphere. These filaments of carbon, although naturally quite fragile owing to their length and small mass, had a smaller radiating surface and higher resistance than we had dared hope. We had virtually reached the position and condition where the carbons were stable. In other words, the incandescent lamp as we still know it to-day, in essentially all its particulars unchanged, had been born.

We began immediately to make vacuum pumps and to produce these paper filament lamps on them. During that November we made perhaps as many as 100 of such lamps, and the same month saw us plunged deep in experiments and inventions on dynamos, regulators, meters, circuits, etc., all just as necessary to the success of the art as the little lamp itself. Some of those paper filament lamps had a remarkably long life. Each yielded from 12 to 16 candle-power and they were burned on chandeliers until they gave out. The average life was about 300 hours, so that commercial success and a new industry were already well in sight.

BAMBOO FILAMENTS

But I was not quite satisfied as to paper, or even with the more regular and homogenous wood fibre filaments, and thus came to take up bamboo. We happened to have a palm-

leaf fan on one of the tables. I was then investigating everything with a microscope, so I picked it up and found that it had a rim on the outside, of bamboo, a very long strip cut from the outer edge. We soon had that cut up into blanks and carbonised. On putting these filaments into the lamps we were gratified to see that the lamps were several times better than any we had succeeded in making before. I soon ascertained why and started a man off for Japan on a bamboo hunt. Before I got through I had tested no fewer than 6,000 vegetable growths, and had ransacked the world for the most suitable bamboo. The use of bamboo was maintained for many years, until other processes dealing with such material as cellulose had been perfected. We tried even at the earliest moment of success a number of experiments and things afterward taken up again or followed through, as for example, burning the paper filaments in a vacuum charged with inert gas; and a little later, in 1880, we also "flashed" the filaments with gasolene vapour.

A CROWNING SUCCESS

The furore that followed the announcements from Menlo Park as to the successful subdivision of the electric light in a commercial incandescent lamp will be well remembered by many of the readers of this. The feasibility of such a thing had been denied by some of the greatest minds in electricity, but here it was; and along

lines that have endured to this day. The best story at the time was given to the world by the New York *Herald* in December, 1879, and on Christmas Day I had already lighted up my laboratory, my offices, two or three houses about one-fifth of a mile from the dynamo plant, and some twenty street lights. On the last day of the year some 3,000 people flocked out to Menlo Park to see it for themselves — and the rest everybody knows.

It is interesting to note that in addition to those mentioned above I had around me other men who ever since have remained active in the field, such as Messrs. Francis Jehl, W. J. Hammer, Martin Force, Ludwig Boehm, not forgetting that good friend and co-worker, the late John Kruesi. They found plenty to do in the various developments of the art, and as I now look back I sometimes wonder how we did so much in so short a time. Early in the spring of 1880 I lighted up for Mr. Villard the Oregon Steam Navigation Company's steamer *Columbia*, and it was not long before the Edison plants began to multiply. Meantime lamp making took on large proportions in two factories of mine, one at old Menlo Park and the other at Newark, and much of my energy was being devoted to cheapening the price of the lamp as well as increasing its life and its candle-power per watt. I am told that upon a moderate computation the production of incandescent lamps in this country since my first success has reached a

total of 250,000,000 lamps, or not less than 10,000,000 a year for each of the twenty-five years. Essentially, the lamp has remained structurally the same ever since 1879, in the elements then demonstrated to be essentially vital and necessary to commercial success.

EDWARD GOODRICH ACHESON

MASTER OF THE ELECTRICAL FURNACE

[Edward Goodrich Acheson was born March 9, 1856, in Washington, Pennsylvania. He is a remarkable example of an inventor who has achieved great success by sticking to one thing. He took care, however, to choose a great thing, carbon, much the most important chemical element, and to treat it by wholly new stresses of electric heat. He has thus won three golden gifts for science and art: — Carborundum, a form-bestower, second only in value to the diamond; artificial graphite, fourfold better than natural graphite as a conveyer of electricity; and oildag, a lubricant which lowers the friction-tax by nearly one-half. Mr. Acheson is in the prime of his powers, and triumphs equal to those he has already attained may be expected at his hands within the next decade of his experiments. The pages which follow have been taken from a lecture which he has delivered at the Massachusetts Institute of Technology, at Cornell University, and at Lafayette College. — ED.]

AN ASSISTANT TO EDISON

LEAVING an academy in 1872 in my seventeenth year, I became a time-keeper at a blast furnace; I later joined a civil engineer corps on railroad construction; then I was ticket clerk on a railroad; again I was at civil engineering on a railroad; then I measured and computed the capacities of oil tanks in the oil country; then I was for a time bookkeeper; then I mined iron ore for a living, and on the first day of September, 1880, I left West-

ern Pennsylvania for my first trip to New York City with the avowed intention of obtaining clerical work. The twelfth day of the month saw me located with Mr. Edison at Menlo Park as assistant draftsman. Within a few weeks I had formed the personal acquaintance of Mr. Edison and was moved from the drafting room to the original experimental department. In the following winter Mr. Edison, who was strenuously endeavouring to find the best material for the filament of his lamp, directed me to experiment upon the production of a filament of graphite. He encouraged me by promising me a prize of $100 when I succeeded in making a flat loop of graphite measuring one inch outside diameter, the filament to be twenty-five thousandths wide and two-thousandths of an inch thick, the same being capable of mounting in a glass globe.

With proper facilities for purifying the graphite, hydraulic press for pressing sheets, and dies for cutting out the loop, I made, I think, about 16,000 of these filaments, having succeeded in making them one-half what was requested by Edison, or one-thousandth of an inch thick.

You will certainly think that I was a "rolling stone," and I can assure you that there was no "moss" on me, of the kind that passes current on Wall Street. On the 20th of the following July I sailed out of New York harbour as first assistant engineer for the Edison interests at

the Electrical Exposition in Paris. I had the pleasure, sometimes, and the undoubted honour always, of installing the first commercial incandescent lighting plants in Holland, Belgium, and Italy.

You will note that in this brief history no mention is made of higher education. I was frequently thrown with college bred men, prominent among whom I would mention particularly Dr. Edward L. Nichols, now Professor of Physics at Cornell University, whom I found with Mr. Edison at Menlo Park when I went there in 1880. A strong and lasting friendship sprang up between us, and I greedily absorbed what I could of the knowledge he freely parted with.

MAKES CRYSTALS ALMOST AS HARD AS DIAMONDS

In the latter part of the year 1880 I had brought to my attention the value of an abrasive material by a remark incidentally made by Mr. George F. Kunz, of Tiffany & Co., New York. While making some experiments in 1886, I passed a quantity of hydrocarbon gas over highly heated clay, and observed that the clay became impregnated with carbon, and I thought it was increased in hardness by the presence of the carbon. In the early part of the year 1891, having at my command an electric generating plant of considerable capacity, and looking about for a line of experiments, I thought to try the impreg-

nating of clay with carbon under the influence of the high heat obtainable with the electric current.

I mixed together a quantity of clay and powdered coke, placed the mixture in an iron bowl such as plumbers use for holding their melted solder. Into this mixture I inserted one end of an electric lamp carbon, the other end being connected to one lead from a dynamo, the other lead being attached to the iron bowl. A good strong current was sent through the mixture until the central portion of the clay was thoroughly melted. When cold the mass was removed and examined carefully. Adhering to the end of the carbon rod I noticed a very few small bright specks. With difficulty I secured one and placing it on the end of a lead pencil, drew it across a pane of glass. It not only scratched but cut the glass. I had found the rough, uncut gem.

Appreciating the possible value of my discovery, and notwithstanding the exceedingly minute quantity of crystals produced, I undertook further experiments, and if I am not mistaken, two months or more had passed before I had enough crystals to fill a small vial measuring about three-eighths of an inch by one inch. Naturally I early undertook to prove its value as an abrasive. I mounted an iron disc in a lathe, charged its surface with oil and my new, then unnamed, product, and with this revolving disc cut the polished face off this diamond on

my finger. (You may appreciate why I wear it and hold it at a value much above its commercial worth.)

Having filled my little vial, I placed it in my vest pocket and went to New York where I had a diamond cutter use some of my new material for the re-polishing of my diamond. I had named it while on the way to New York. I called it carborundum, under the belief that it contained carbon and corundum. The diamond cutter bought what was left of the material at the price of 30 cents per karat, and with the proceeds I purchased a microscope to assist me in the further study of the material.

Soon after this I learned that it was the silica in the clay and not the alumina that was associating itself with the carbon, and before long I had quit the use of the clay, having substituted sand.

I had devised an electric furnace in which a resistant material formed a central core around which was placed the material to be heated, and this probably was the first furnace wherein thermal and chemical effects were produced within the mass of material operated upon, the outer portions of the mass acting as retaining walls. It is thus that we can work at higher temperatures than would be possible were we required to depend upon the furnace walls proper.

The history of the development of carbo-

rundum is overflowing with trials, tribulations, and glorious triumphs. In 1894 the Carborundum Company, a company I had formed to develop the business, was located at Monongahela City in Western Pennsylvania, and it was operating a steam generating plant of 134 horse power. The cost of production was so high that the trade was restricted to lapidaries, valve grinding, and kindred lines that could afford to buy it, and but one-half its production was sold. The new electrical development at Niagara Falls was at this time approaching completion. I went to Niagara Falls, looked over the situation, possibilities, and prices. On my return I convened a meeting of my board of directors and laid before them a scheme of moving to Niagara Falls and there building and equipping a plant for 1,000 horse power.

To build a plant for 1,000 horse power, in view of the fact that we were only selling one-half of the output from a 134 horse power one, was a trifle too much for my conservative directors, and they one and all resigned, arose, and left the room. Fortunately I was in control of the destinies of the Carborundum Company. I organised a new board, proceeded with my plans, and in the year 1904, the thirteenth one from the date of the discovery, the Carborundum Company had a plant equipped with 5,000 electrical horse power, and produced over 7,000,000 pounds of those specks I had picked

off the end of the electric lamp carbon in the spring of 1891.

IMPROVES UPON NATURAL GRAPHITE

Some years ago I discovered that when carborundum was heated to a very high temperature, decomposition occurred, the contained silicon was dissipated in vapour, and a beautiful graphite was left as a skeleton of the original carborundum crystal. This discovery started me on a new line of thought, and as a result of a long series of experiments the present methods of the International Acheson Graphite Company were perfected.

The products of this company in the form of rods, bars, and plate are extensively used by the electrochemical and electrometallurgical industries, almost to the exclusion of amorphous carbon, which they formerly used, not only in America but throughout Europe. In the pulverised form, it is used extensively as a filler in dry batteries. It is rapidly growing in favour for stove polish, lubrication, foundry facings, and as a paint pigment. It is particularly well adapted for paint, being a very pure form of carbon, free from oxides and readily reduced to a very fine powder.

It is possible to produce practically chemically pure carbon by our methods, but the cost increases as this condition is approached, and for commercial purposes the purity of 99.5 per

cent. is adopted for electrodes for use in electrochemical and electrometallurgical work, while for the paint and kindred uses 97 per cent. is the standard. When it is remembered that a good quality of natural graphite contains but 85 per cent. carbon, while most of that sold in the market runs as low as 45 per cent., it will be appreciated that our product is unique. For electrical work it is almost ideal. A rod or bar of this graphite is graphite throughout. It is not made up of small graphite particles held together by a binding agent; it can be cut, planed, tapped and threaded like a metal; its electrical conductivity is about four times that of a similar sized rod of amorphous carbon. Its rate of disintegration in electrochemical work is very slow. In some lines of work it lasts twelve times as long as amorphous carbon.

I early hoped to introduce my newly made graphite into the crucible trade, which I knew to be a large user of the natural product. It was found to be too porous, offering too large a surface for oxidation, and my experiments on this line were not productive of success. Mr. Edison used to tell me every experiment had its value. It either accomplished the result sought for or it taught you what lines to avoid. My failure to make a successful crucible of graphite put me, so to speak, on my mettle, and from then on I was on a constant watch for a suitable material, and I now hope and believe

I have found one capable of making a better crucible than either graphite or clay.

MATERIAL FOR CRUCIBLES

During the latter part of the summer of 1899 I became interested in the direct reduction of silicon, and one of my early experiments was to intimately mix, in fact rub together, fine, soft, pure graphite and silica, so proportioned as to provide the necessary carbon for the reduction. The quantity, distribution, and conductivity of the graphite was sufficient to carry the necessary current. After the current had been passed for some time, the furnace cooled and opened, a small quantity of metallic silicon was found disseminated in and held as distinct particles throughout a loose bulky mass of a greenish gray substance. The loose, fluffy character of this material, together with the knowledge that it had been formed or a least existed in the path and at the temperature of the reduction of silicon, caused me immediately to recognise the fact that it was a highly refractory body. . . .

This discovery was followed by much analytical and experimental work. The substance was found to be composed of silicon, carbon, and oxygen of varying proportions, a typical formula being Si_2C_2O. It was found to be amorphous, inert to both acid and basic slags, insoluble in melted iron, self-bonding when pressed tightly together and heated to about 2,500 degrees F.

and absolutely infusible, its inevitable destruction occurring as decomposition at a very high but as yet undetermined temperature, the silicon, oxygen, and a part of the carbon passing away as vapour or gas, while a part of the carbon remains as graphite occupying the space of the destroyed body, which I have named siloxicon from the words silicon and oxygen.

SUCCESS FROM FAILURE

In my own work I have been so fortunate as to have repeatedly turned failure into success. In the debris of the melted clay and carbon mixture, which proved a failure for the purpose I had in view, my attention was riveted on the unexpected bright specks. The present size of the carborundum industry indicates my appreciation of the possible value of this discovery. Again it was not the small quantity of metallic silicon I made in my experiment in 1899 that interested me most. True, it furnished evidence of my theories of the possible reduction having been correct, but I realised that the loose, bulky material I discovered occupying the major part of the furnace might prove vastly more valuable.

Reviewing this sketch, I would sum up the dominant qualities determining the success of the discoverer and inventor to be: 1. Optimism. 2. Imagination. 3. Observation of small things. 4. Appreciation of the possible value of the new. 5. Knowledge of the existing art.

6. Self-reliance. 7. Having the determination to attain an end. 8. Indomitable perseverance, and I might add a 9th (valuable particularly to the inventor) proper assistance. My own work has been so varied and extensive, it would have been difficult to accomplish had I not received earnest, loyal, and valuable support, and from no one did I receive this more fully than from Mr. F. A. J. Fitzgerald.

PIERRE CURIE

[In 1903 Pierre Curie accorded an interview to Mr. Cleveland Moffett, published in the *McClure's Magazine*, November, 1903. By the kind permission of the S. S. McClure Co., New York, part of that interview is presented. — Ed.]

Describes Radium, Which His Wife and He Discovered

Very well do I remember my first impression of M. Curie. It was in the Rue Cuvier, at the Sorbonne Laboratories in Paris, where he was lecturing that day in the big amphitheatre, while I waited in an adjoining room among the air-pumps and electrical apparatus. Suddenly a door opened and there came a burst of applause, a long clapping of hands, and at the same moment a tall, pale man, slightly bent, walked across the room.

On this occasion I simply made an appointment to see M. Curie the next morning at the École de Physique; but I profited by the opportunity to ask his assistant, M. Danne, some preliminary questions about radium. Was it true, *could* it be true, that this strange substance gives forth heat and light ceaselessly and is really an inexhaustible source of energy? Of course, I had read all this, but I wanted to hear it from the mouth of one who knew.

"It is quite true," said M. Danne, "that pure radium gives out light and heat without any waste or diminution that can be detected by our most delicate instruments. That is all we can say."

"Is the light that it gives a bright light?"

"Reasonably bright. M. Curie will show you."

"Can he explain it? Can any one explain it?"

"There are various theories, but they really explain very little."

M. Danne went on to indicate other properties of radium that are scarcely less startling than these. Besides heat and light this strange metal gives out constantly three kinds of invisible rays that move with the velocity of light, or thereabouts, and that have separate and well-marked attributes. These rays may be helpful or harmful, they may destroy life or stimulate it. They are capable not only of shortening life or prolonging it, but of modifying existing forms of life — that is, of actually creating new species. Finally, by destroying bacteria, they may be used to cure disease, notably the dread lupus, recently conquered by Finsen's lamps, and now apparently conquered again by a simpler means.

I listened in amazement; it was not one discovery, but a dozen, that we were contemplating.

"And — all this is M. Curie's discovery?"

"Radium is his discovery; that is, his and Mme. Curie's. You cannot give one more credit than the other. They did it together."

He told me a little about Mme. Curie, who, it appears, was a Polish student in the Latin Quarter, very poor, but possessed of rare talents. They say that her marriage with M. Curie was just such a union as *must* have produced some fine result. Without his scientific learning and vivid imagination it is doubtful if radium would ever have been dreamed of, and without her determination and patience it is likely the dream would never have been realised.

The next day I found M. Curie in one of the rambling sheds of the École de Physique bending over a small porcelain dish, where a colourless liquid was simmering, perhaps half a teacupful, and he was watching it with concern, always fearful of some accident. He had lost nearly a decigramme (1.5 grains troy) of radium, he said, only a few weeks before in a curious way. He had placed some radium salts in a small tube, and this inside another tube, in which he created a vacuum. Then he began to heat both tubes over an electric furnace, when, suddenly, at about 2,000 degrees F., there came an explosion which shattered the tubes and scattered their precious contents. There was absolutely no explanation of this explosion; it was one of the tricks that radium is apt to play on you. Here his face lightened with quite a boyish smile.

M. Curie proceeded to explain what he was doing with the little dish; he was refining some radium dissolved in it — that is, freeing

it from contaminating barium by repeated crystallisation, this being the last and most delicate part of the process of obtaining the pure metal.

"We have our radium works outside Paris," he said, "where the crude ore goes through its early stages of separation and where the radium is brought to an intensity of 2,000, as we express it. After that the process requires such care and involves so much risk of waste that we keep the precious stuff in our own hands and treat it ourselves, my wife and I, as I am doing now, to bring it to the higher intensities, 50,000, 200,000, 500,000, and, finally, 1,500,000. What you see here is about 100,000. It will take many more crystallisations to bring it to the maximum."

"That is, to the state of pure radium?"

"To the state of pure chloride of radium. You know the metal exists only as a chloride or bromide. It has never yet been isolated, although it easily might be."

"Why has it never been isolated?"

"Because it would not be stable; it would immediately be oxidised by the air and destroyed, as happens with sodium, whereas it remains permanent as a bromide or chloride and suffers no change."

DANGER FROM RADIUM

"Does radium change in appearance as it increases in intensity?" I asked.

"No; it keeps the form of small white crystals,

which may be crushed into a white powder, and which look like ordinary salt. See, here are some."

He took from the table drawer a small glass tube, not much larger than a thick match. It was sealed at both ends and partly covered with a fold of lead. Inside the tube I could see a white powder.

"Why is the tube wrapped with lead?" I inquired.

"For the protection of those who handle it. Lead stops the harmful rays, that would otherwise make trouble."

"Trouble?"

"Yes; you see the radium in this tube is very active; it has an intensity of 1,500,000. and if I were to lay it against your hand or any part of your body, so" — he touched my hand with the bare tube — "and if I were to leave it there for a few minutes, you would certainly hear from it later."

"But I feel nothing."

"Of course not; neither did I feel anything when I touched some radium here," and pulling up his sleeves he showed me a forearm scarred and reddened from fresh-healed sores. "But you see what it did, and it was much less intense than this specimen."

He then mentioned an experience of his friend, Professor Becquerel, discoverer of the "Becquerel rays" of uranium, and in a way the parent-discoverer of radium, since the latter

discovery grew out of the former. It seems that Professor Becquerel, in journeying to London, carried in his waistcoat pocket a small tube of radium to be used in a lecture there. Nothing happened at the time, but about a fortnight later the professor observed that the skin under his pocket was beginning to redden and fall away, and finally a deep and painful sore formed there and remained for weeks before healing. A peculiar feature of these radium sores is that they do not appear for some considerable time after exposure to the rays.

"Then radium is an element of destruction?" I remarked.

"Undoubtedly it has a power of destruction, but that power may be tempered or controlled, for instance, by this covering of lead. M. Danysz, at the Pasteur Institute, will give you the pathological facts better than I can."

LIGHT AND HEAT FROM RADIUM

This brought us back to physical facts, and I asked M. Curie if the radium before us was at that moment giving out heat and light, for I could perceive neither.

"Of course it is," he replied. "I will take you into a dark room presently and let you see the light for yourself. As for the heat, a thermometer would show that this tube of radium is 2.7 degrees F. warmer than the surrounding air."

"Is it always that much warmer?"

"Always — so far as we know. I may put it more simply by saying that a given quantity of radium will melt its own weight of ice every hour."

"For ever?"

He smiled. "So far as we know — for ever. Or, again, that a given quantity of radium throws out as much heat in eighty hours as an equal weight of coal would throw out if burned to complete combustion in one hour."

"Suppose you had a considerable quantity of radium," I suggested, "say twenty pounds, or a hundred pounds?"

"The law would be the same, whatever the quantity. If we had fifty kilos (110 pounds) of radium"— he gave a little wondering cluck at the thought — "I say *if* we had fifty kilos of radium it would give out as much heat *continuously* as a stove would give out that burned ten kilos (twenty-two pounds) of coal every twenty-four hours, and was filled up fresh every day."

"And the radium would *never* cease to give out this heat and would *never* be consumed?"

"Never is a hard word, but one of our professors has calculated that a given quantity of radium, after throwing out heat as I have stated for a thousand million years, would have lost only one-millionth part of its bulk. Others think the loss might be greater, say an ounce to a ton in ten thousand years, but in any case it is so infinitesimally small that we have no means

of measuring it, and for practical purposes it does not exist."

After this M. Curie took me into a darkened room, where I *saw* quite plainly the light from the radium tube, a clear glow sufficient to read by if the tube were held near a printed page. And, of course, this was a very small quantity of radium, about six centigrammes (nine-tenths of a grain Troy).

"We estimate," said he, "that a decigramme of radium will illuminate a square décimètre (fifteen square inches) of surface sufficient for reading."

"And a kilogramme (2.2 pounds) of radium?"

"A kilogramme of radium would illuminate a room thirty feet square with a mild radiance; and the light would be much brighter if screens of sulphide of zinc were placed near the radium, for these are thrown by the metal into a brilliant phosphorescence."

"Then radium may be the light of the future?"

M. Curie shook his head. "I am afraid that we should pay rather dearly for such a light. There is first the money cost to be considered, and then the likelihood that the people illuminated by radium would be also stricken with paralysis, blindness, and various nervous disorders. Possibly protective screens might be devised against these dangers, but it is too soon to think of that. For a long time to come, then radium light will be only a laboratory wonder."

After we had been in the darkness for some time M. Curie wrapped the radium tube in thick paper and put it in my hand.

"Now," said he, "shut your eyes and press this against your right eyelid."

I did as he bade me, and straightway had the sensation of a strange diffused light outside my eye. M. Curie assured me, however, that the light was not outside but *inside* the eye, the radium rays having the property of making the liquids of the eyeball self-luminous, a sort of internal phosphorescence being produced. He warned me that it would be dangerous to leave the radium against the eyelid very long, as a serious disturbance to the eyesight, or even blindness, might result.

Another experiment consisted in placing the radium against the bone at the side of the forehead, and even in this position, with the eyes closed, a light was perceptible, although fainter. Here the radium rays had acted upon the eyeball through the bones of the head.

"It is possible," said M. Curie, "that this property of radium may be utilised in certain diseases of the eye. Dr. Emile Javal, one of our distinguished physicians, who is blind himself, has given this matter particular attention, and he thinks that radium may offer a precious means of diagnosis in cases of cataract, by showing whether the retina is or is not intact, and whether an operation will succeed. If a person blind from cataract can see the radium

light as you have just seen it, then the eyesight of that person may be restored by removing the cataract. Otherwise it cannot be restored."

WHY RADIUM IS SO RARE

As we returned to the laboratory I remarked that the quantity of radium in the various tubes I had seen was very small.

"Of course it is small," he sighed; "there is very little radium in the world. I mean very little that has been taken from the earth and purified."

"How much is there?"

He thought a moment. "We have about one gramme (one-third of an ounce) in France, Germany may have one gramme, America has less than one gramme, and the rest of the world may perhaps have half a gramme. Four grammes in all would be an outside estimate; you could heap it all in a tablespoon."

I suggested to M. Curie the possibility that some philanthropist might be inspired on reading his words to help the new cause. And I remarked that great things could doubtless be accomplished with some substantial quantity of radium, say a pound or two.

He gave me an amused look and asked if I had any idea what a pound or two of radium, say a kilogramme (two and one-fifth pounds), would cost.

"Why, no," said I, "no exact idea; but ——"

"A kilogramme of radium would cost"—

he figured rapidly on a sheet of paper —"with the very cheapest methods that we have of purifying the crude material, it would cost about ten million francs ($1,860,000). Under existing conditions radium is worth about three thousand times its weight in pure gold."

"And yet there may be tons of it in the earth?"

M. Curie was not so sure of this. "It is doubtful," said he, "if there is very much radium in the earth, and what there is is so thinly scattered in the surrounding ore — mere traces of radium for tons of worthless rock — that the cost of extracting it is almost prohibitive. You will realise this when you visit our works at Ivry."

These works I visited the next day, and found myself outside the walls of Paris, near the old Ivry Cemetery, where some unpretentious sheds serve for this important business of radium extraction. One of the head men met me and explained, step by step, how they obtain this strange and elusive metal. First he showed me a lumpy reddish powder, sacks of it, brought from Bohemia by the ton, and constituting the raw material from which the radium is extracted. This powder is the refuse from uranium mines at Joachimsthal; that is, what remains of the original uranite ore, *pitchblende*, after the uranium has been removed. For years this refuse was regarded as worthless, and was left to accumulate in heaps, tons of it, quite at the disposal of whoever chose to cart

it away. Now that it is known to contain the rarest and most precious substance in the world, it goes without saying that the owners have begun to put a price on it.

My informant referred with proper pride to the difficulties that had confronted them when they started these radium works in 1901. It was a new problem in practical chemistry to bring together infinitesimal traces of a metal lost in tons of debris. It was like searching for specks of dust hidden in a sand-heap, or for drops of perfume scattered in a river. Still, they went at it with good heart, for the end justified the effort. If it took a ton of uranite dust to yield as much radium as would half fill a doll's thimble, then the thing to do was to have many tons of this dust sent on from Bohemia, and patiently to accumulate, after months of handling, various pinches of radium, a few centigrammes, then a few decigrammes, and finally some day — who could tell? —they might get as much as a gramme. This was a distant prospect, to be sure, yet with infinite pains and all the resources of chemistry it might be attained. Well, now they had attained it, and at this time, he said, some eight tons of uranite detritus had passed through the caldrons and great glass jars and muddy barrels of the Ivry establishment, had been boiled and filtered and decanted and crystallised, with much fuming of acids and the steady glow of furnaces; and out of it all, for the twenty-four months'

effort, there had come just about a gramme of practically pure chloride of radium — enough white powder to fill a salt-spoon.

When next I saw M. Curie he had just returned from London, where he had lectured before the Royal Institution. His hands were much peeled, and very sore from too much contact with radium, and for several days he had been unable to dress himself; but he took it good-naturedly, and proceeded to describe some of the experiments he had made before British scientists.

In order to demonstrate that radium throws off heat continually he took two glass vessels, one containing a thermometer and a tube of radium, the other containing a thermometer and no radium. Both vessels were closed with cotton, and it was presently seen that the thermometer in the vessel containing the radium registered constantly 5.4 degrees F. higher than the thermometer which was not so influenced.

RADIUM EMANATIONS

The most striking experiment presented by M. Curie in his London lecture was one devised by him to prove the existence of radium emanations, a kind of gaseous product (quite different from the rays) which this extraordinary metal seems to throw off constantly as it throws off heat and light. These emanations may be regarded as an invisible vapour of radium, like water vapour, only infinitely more subtle,

which settles upon all objects that it approaches and confers upon them, for a time at least, the mysterious properties of radium itself. Thus the yellow powder sulphide of zinc bursts into a brilliant glow under the stimulus of radium emanations, and M. Curie proves that this effect is due to the emanations and not to the rays.

Dwelling upon the extreme attenuation of these radium emanations, M. Curie mentioned a recent experiment, in which he had used a platinum box pierced by two holes so extremely small that the box would retain a vacuum, yet not small enough to resist the passage of radium emanations.

In view of the extreme rarity and costliness of radium, it is evident that its emanations may be put to many important uses in and out of the laboratory, since they bestow upon indifferent objects — a plate, a piece of iron, an old shoe, anything — the very properties of radium itself. Thus a scientist or a doctor unable to procure the metal radium may easily experiment with a bit of wood or glass rendered radio-active — that is, charged by radium emanations, and capable of replacing the original metal as long as the charge keeps its potency. This period has been determined by the Curies after observations extending over weeks and months, and applied to all sorts of substances, copper, aluminum, lead, rubber, wax, celluloid, paraffin, no fewer than fifty in all, the resulting conclusions being formulated in a precise law as follows:

(1) All substances may be rendered radio-active through the influence of radium emanations.

(2) Substances thus influenced retain their induced radio-activity very much longer when guarded in a small enclosure through which the emanations cannot pass (say a sealed glass tube) than when not so guarded. In the former case their radio-activity diminishes one-half every four days. In the latter case it diminishes one-half every twenty-eight minutes.

ANDREW CARNEGIE

[Andrew Carnegie is an eminent master of the science of industry. He owes much to the metallurgists, chemists, and engineers who have formed his staffs, and laid their knowledge and skill at his disposal. In acknowledgment of this debt he has bestowed vast gifts not only upon education in the laboratory and the workshop, the classroom and the public library, but he has founded the Carnegie Institution of Washington, for original research, endowing it to December, 1907, with twelve millions. He is fully aware that many investigations, ultimately of incalculable worth, in their early stages have no value in the marketplace.

Mr. Carnegie has found time, amid his multiplied toils, to be an author. His writings include "The Gospel of Wealth," published by the Century Company, New York; and "The Empire of Business," published by Doubleday, Page & Co., New York. In the pages which follow he tells the story of his apprenticeship, as published in the *Youth's Companion*, Boston, April 23, 1896. Hearty thanks are given to Mr. Carnegie and to the editors of the *Youth's Companion* for permission to repeat this recital. It appears also in the book, just mentioned, entitled "The Gospel of Wealth." — Ed.]

"How I Served My Apprenticeship"

WHY I BECAME A BUSINESS MAN

It is a great pleasure to tell how I served my apprenticeship as a business man. But there seems to be a question preceding this: Why did I become a business man? I am sure that I should never have selected a business career if I had been permitted to choose.

Andrew Carnegie

The eldest son of parents who were themselves poor, I had, fortunately, to begin to perform some useful work in the world while still very young in order to earn an honest livelihood, and was thus shown even in early boyhood that my duty was to assist my parents and, like them, become, as soon as possible, a bread-winner in the family. What I could get to do, not what I desired, was the question.

When I was born my father was a well-to-do master weaver in Dunfermline, Scotland. He owned no less than four damask-looms and employed apprentices. This was before the days of steam-factories for the manufacture of linen. A few large merchants took orders, and employed master weavers, such as my father, to weave the cloth, the merchants supplying the materials.

As the factory system developed hand-loom weaving naturally declined, and my father was one of the sufferers by the change. The first serious lesson of my life came to me one day when he had taken in the last of his work to the merchant, and returned to our little home greatly distressed because there was no more work for him to do. I was then just about ten years of age, but the lesson burned into my heart, and I resolved then that the wolf of poverty should be driven from our door some day, if I could do it.

The question of selling the old looms and starting for the United States came up in the family council, and I heard it discussed from

day to day. It was finally resolved to take the plunge and join relatives already in Pittsburg. I well remember that neither father nor mother thought the change would be otherwise than a great sacrifice for them, but that "it would be better for the two boys."

In after life, if you can look back as I do and wonder at the complete surrender of their own desires which parents make for the good of their children, you must reverence their memories with feelings akin to worship.

A BOBBIN-BOY

On arriving in Allegheny City (there were four of us: father, mother, my younger brother, and myself), my father entered a cotton factory. I soon followed, and served as a "bobbin-boy," and this is how I began my preparation for subsequent apprenticeship as a business man. I received one dollar and twenty cents a week, and was then just about twelve years old.

I cannot tell you how proud I was when I received my first week's own earnings. One dollar and twenty cents made by myself and given to me because I had been of some use in the world! No longer entirely dependent upon my parents but at last admitted to the family partnership as a contributing member and able to help them! I think this makes a man out of a boy sooner than almost anything else, and a real man, too, if there be any germ of true manhood in him. It is everything to feel that you are useful.

I have had to deal with great sums. Many millions of dollars have since passed through my hands. But the genuine satisfaction I had from that one dollar and twenty cents outweighs any subsequent pleasure in money-getting. It was the direct reward of honest, manual labor; it represented a week of very hard work — so hard that, but for the aim and end which sanctified it, slavery might not be much too strong a term to describe it.

For a lad of twelve to rise and breakfast every morning, except the blessed Sunday morning, and go into the streets and find his way to the factory and begin to work while it was still dark outside, and not be released until after darkness came again in the evening, forty minutes' interval only being allowed at noon, was a terrible task.

But I was young and had my dreams, and something within always told me that this would not, could not, should not last — I should some day get a better position. Besides this, I felt myself no longer a mere boy, but quite a little man, and this made me happy.

RUNS AN ENGINE

A change soon came, for a kind old Scotchman, who knew some of our relatives, made bobbins, and took me into his factory before I was thirteen.

But here for a time it was even worse than in the cotton factory, because I was set to fire a boiler in the cellar, and actually to run the small steam-

engine which drove the machinery. The firing of the boiler was all right, for fortunately we did not use coal, but the refuse wooden chips; and I always liked to work in wood. But the responsibility of keeping the water right and of running the engine, and the danger of my making a mistake and blowing the whole factory to pieces, caused too great a strain, and I often awoke and found myself sitting up in bed through the night, trying the steam gauges. But I never told them at home that I was having a hard tussle. No, no! everything must be bright to them.

This was a point of honour, for every member of the family was working hard, except, of course, my little brother, who was then a child, and we were telling each other only all the bright things. Besides this, no man would whine and give up — he would die first.

There was no servant in our family, and several dollars per week earned by the mother by binding shoes after her daily work was done! Father was also hard at work in the factory. And could I complain?

My kind employer, John Hay, — peace to his ashes! — soon relieved me of the undue strain, for he needed some one to make out bills and keep his accounts, and finding that I could write a plain school-boy hand and could "cipher," he made me his only clerk. But still I had to work hard upstairs in the factory, for the clerking took but little time.

You know how people moan about poverty as being a great evil, and it seems to be accepted that if people had only plenty of money and were rich, they would be happy and more useful, and get more out of life.

As a rule, there is more genuine satisfaction, a truer life, and more obtained from life in the humble cottages of the poor than in the palaces of the rich. I always pity the sons and daughters of rich men, who are attended by servants, and have governesses at a later age, but am glad to remember that they do not know what they have missed.

They have kind fathers and mothers, too, and think that they enjoy the sweetness of these blessings to the fullest; but this they cannot do ; for the poor boy who has in his father his constant companion, tutor, and model, and in his mother — holy name! — his nurse, teacher, guardian angel, saint, all in one, has a richer, more precious fortune in life than any rich man's son who is not so favoured can possibly know, and compared with which all other fortunes count for little.

It is because I know how sweet and happy and pure the home of honest poverty is, how free from perplexing care, from social envies and emulations, how loving and how united its members may be in the common interest of supporting the family, that I sympathise with the rich man's boy and congratulate the poor man's boy; and it is for these reasons that from the

ranks of the poor so many strong, eminent, self-reliant men have always sprung and always must spring.

If you will read the list of the immortals who "were not born to die," you will find that most of them have been born to the precious heritage of poverty.

It seems, nowadays, a matter of universal desire that poverty should be abolished. We should be quite willing to abolish luxury, but to abolish honest, industrious, self-denying poverty would be to destroy the soil upon which mankind produces the virtues which enable our race to reach a still higher civilisation than it now possesses.

A TELEGRAPH OPERATOR

I come now to the third step in my apprenticeship, for I had already taken two, as you see — the cotton factory and then the bobbin factory; and with the third —the third time is the chance you know — deliverance came. I obtained a situation as messenger boy in the telegraph office of Pittsburg when I was fourteen. Here I entered a new world.

Amid books, newspapers, pencils, pens and ink, and writing-pads, and a clean office, bright windows, and the literary atmosphere, I was the happiest boy alive.

My only dread was that some day I should be dismissed because I did not know the city; for it is necessary that a messenger boy should

know all the firms and addresses of men who are in the habit of receiving telegrams. But I was a stranger in Pittsburg. However, I made up my mind that I would learn to repeat successively each business house in the principal streets, and was soon able to shut my eyes and begin at one side of Wood Street, and call every firm successively to the top, then pass to the other side and call every firm to the bottom. Before long I was able to do this with the business streets generally. My mind was then at rest upon the point.

Of course every ambitious messenger boy wants to become an operator, and before the operators arrive in the early mornings the boys slipped up to the instruments and practised. This I did, and was soon able to talk to the boys in other offices along the line, who were also practising.

One morning I heard Philadelphia calling Pittsburg, and giving the signal, "Death message." Great attention was then paid to "death messages," and I thought I ought to try this one. I answered and did so, and went off and delivered it before the operator came. After that the operators sometimes used to ask me to work for them.

Having a sensitive ear for sound, I soon learned to take messages by the ear, which was then very uncommon — I think only two persons in the United States could then do it. Now every operator takes by ear, so easy is it to follow

and do what any other boy can — if you only have to. This brought me into notice, and finally I became an operator, and received the, to me, enormous recompense of twenty-five dollars per month — three hundred dollars a year!

This was a fortune — the very sum that I had fixed when I was a factory-worker as the fortune I wished to possess, because the family could live on three hundred dollars a year and be almost or quite independent. Here it was at last! But I was soon to be in receipt of extra compensation for extra work.

The six newspapers of Pittsburg received telegraphic news in common. Six copies of each despatch were made by a gentleman who received six dollars per week for the work, and he offered me a gold dollar every week if I would do it, of which I was very glad indeed, because I always liked to work with news and scribble for newspapers.

The reporters came to a room every evening for the news which I had prepared, and this brought me into most pleasant intercourse with these clever fellows, and besides, I got a dollar a week as pocket money, for this was not considered family revenue by me.

I think this last step of doing something beyond one's task is fully entitled to be considered "business." The other revenue, you see, was just salary obtained for regular work; but here was a little business operation upon my own

account, and I was very proud indeed of my gold dollar every week.

ENTERS UPON RAILROADING

The Pennsylvania Railroad shortly after this was completed to Pittsburg, and that genius, Thomas A. Scott, was its superintendent. He often came to the telegraph office to talk to his chief, the general superintendent, at Altoona, and I became known to him in this way.

When that great railway system put up a wire of its own, he asked me to be his clerk and operator; so I left the telegraph office — in which there is great danger that a young man may be permanently buried, as it were — and became connected with the railways.

The new appointment was accompanied by what was, to me, a tremendous increase of salary. It jumped from twenty-five to thirty-five dollars per month. Mr. Scott was then receiving one hundred and twenty-five dollars per month, and I used to wonder what on earth he could do with so much money.

I remained for thirteen years in the service of the Pennsylvania Railroad Company, and was at last superintendent of the Pittsburg division of the road, successor to Mr. Scott, who had in the meantime risen to the office of vice-president of the company.

FIRST INVESTMENT

One day Mr. Scott, who was the kindest of men and had taken a great fancy to me,

asked if I had or could find five hundred dollars to invest.

Here the business instinct came into play. I felt that as the door was opened for a business investment with my chief, it would be wilful flying in the face of providence if I did not jump at it; so I answered promptly:

"Yes, sir; I think I can."

"Very well," he said, "get it; a man has just died who owns ten shares in the Adams Express Company which I want you to buy. It will cost you fifty dollars per share, and I can help you with a little balance if you cannot raise it all."

Here was a queer position. The available assets of the whole family were not five hundred dollars. But there was one member of the family whose ability, pluck, and resource never failed us, and I felt sure the money could be raised somehow or other by my mother.

Indeed, had Mr. Scott known our position he would have advanced it himself; but the last thing in the world the proud Scot will do is to reveal his poverty and rely upon others. The family had managed by this time to purchase a small house and pay for it in order to save rent. My recollection is that it was worth eight hundred dollars.

The matter was laid before the council of three that night, and the oracle spoke: "Must be done. Mortgage our house. I will take

the steamer in the morning for Ohio, and see uncle, and ask him to arrange it. I am sure he can." This was done. Of course her visit was successful — where did she ever fail?

The money was procured, paid over; ten shares of Adams Express Company stock was mine; but no one knew our little home had been mortgaged "to give our boy a start."

Adams Express stock then paid monthly dividends of 1 per cent., and the first cheque for five dollars arrived. I can see it now, and I well remember the signature of "J. C. Babcock, Cashier," who wrote a big "John Hancock" hand.

The next day being Sunday, we boys — myself and my ever-constant companions — took our usual Sunday afternoon stroll in the country, and sitting down in the woods, I showed them this cheque, saying, "Eureka! We have found it."

Here was something new to all of us, for none of us had ever received anything but from toil. A return from capital was something strange and new.

How money could make money, how, without any attention from me, this mysterious golden visitor should come, led to much speculation upon the part of the young fellows, and I was for the first time hailed as a "capitalist."

You see, I was beginning to serve my appren-

ticeship as a business man in a satisfactory manner.

INVESTS IN AN INVENTION

A very important incident in my life occurred when, one day in a train, a nice, farmer-looking gentleman approached me, saying that the conductor had told him I was connected with the Pennsylvania Railroad, and he would like to show me something. He pulled from a small green bag the model of the first sleeping-car. This was Mr. Woodruff, the inventor.

Its value struck me like a flash. I asked him to come to Altoona the following week, and he did so. Mr. Scott, with his usual quickness, grasped the idea. A contract was made with Mr. Woodruff to put two trial cars on the Pennsylvania Railroad. Before leaving Altoona Mr. Woodruff came and offered me an interest in the venture, which I promptly accepted. But how I was to make my payments rather troubled me, for the cars were to be paid for in monthly instalments after delivery, and my first monthly payment was to be $217.50.

I had not the money, and I did not see any way of getting it. But I finally decided to visit the local banker and ask him for a loan, pledging myself to repay at the rate of fifteen dollars per month. He promptly granted it. Never shall I forget his putting his arm over my shoulder, saying, "Oh, yes, Andy; you are all right!"

I then and there signed my first note. Proud day this; and surely now no one will dispute that I was becoming a "business man." I had signed my first note, and, most important of all — for any fellow can sign a note — I had found a banker willing to take it as "good."

My subsequent payments were made by the receipts from the sleeping-cars, and I really made my first considerable sum from this investment in the Woodruff Sleeping-car Company, which was afterward absorbed by Mr. Pullman — a remarkable man whose name is now known over all the world.

Shortly after this I was appointed superintendent of the Pittsburg division, and returned to my dear old home, smoky Pittsburg. Wooden bridges were then used exclusively upon the railways, and the Pennsylvania Railroad was experimenting with a bridge built of cast-iron. I saw that wooden bridges would not do for the future, and organised a company in Pittsburg to build iron bridges.

BEGINS IRON BRIDGE BUILDING

Here again I had recourse to the bank, because my share of the capital was $1,250 and I had not the money; but the bank lent it to me, and we began the Keystone Bridge Works, which proved a great success. This company built the first great bridge over the Ohio River, three hundred feet span, and has built many of the most important structures since.

This was my beginning in manufacturing; and from that start all our other works have grown, the profits of one building the other. My "apprenticeship" as a business man soon ended, for I resigned my position as an officer of the Pennsylvania Railroad Company to give exclusive attention to business.

I was no longer merely an official working for others upon a salary, but a full-fledged business man working upon my own account.

I never was quite reconciled to working for other people. At the most, the railway officer has to look forward to the enjoyment of a stated salary, and he has a great many people to please; even if he gets to be president, he has sometimes a board of directors who cannot know what is best to be done, and even if this board be satisfied, he has a board of stockholders to criticise him, and as the property is not his own he cannot manage it as he pleases.

I always liked the idea of being my own master, of manufacturing something and giving employment to many men. There is only one thing to think of manufacturing if you are a Pittsburger, for Pittsburg even then had asserted her supremacy as the "Iron City," the leading iron and steel manufacturing city in America.

So my indispensable and clever partners, who had been my boy companions, I am delighted to say — some of the very boys who had met in the grove to wonder at the five-dollar cheque — began business, and still continue extending

it to meet the ever-growing and ever-changing wants of our most progressive country, year after year.

Always we are hoping that we need expand no farther; yet ever we are finding that to stop expanding would be to fall behind; and even to-day the successive improvements and inventions follow each other so rapidly that we see just as much yet to be done as ever.

When the manufacturer of steel ceases to grow he begins to decay, so we must keep on extending. The result of all these developments is that three pounds of finished steel are now bought in Pittsburg for two cents, which is cheaper than anywhere else on the earth, and that our country has become the greatest producer of iron in the world.

And so ends the story of my apprenticeship and graduation as a business man.