GORE GEORGE

THE SCIENTIFIC BASIS OF NATIONAL PROGRESS, INCLUDING THAT OF MORALITY

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PREFACE

As there exists at the present time in this country a considerable degree of uneasiness in the public mind respecting our ability to maintain our position in the race of progress, and as our future success as a nation depends largely upon science, it is desirable to call attention to the great public importance of *new* scientific knowledge, and to the means of promoting its development.

Although the illustrations given in this book of the importance of such knowledge to mankind, constitute but a small fraction of the number which might be adduced, they are sufficient to show that by the neglect of scientific investigation, we are sacrificing our welfare as a nation to an enormous extent.

The greatest obstacle to the discovery of new knowledge in this country, lies in a wide spread ignorance of the dependence of human welfare upon scientific research. I propose therefore to show in a brief manner, that the essential starting-point of human progress, lies in scientific discovery; also that new truths are evolved by original research made in accordance with scientific methods; and to illustrate these statements by examples; also to point out how such research can be encouraged.

The book is divided into four chapters, viz.: *1st.* The Scientific basis of Material progress: *2nd.* The Scientific basis of Mental and Moral progress: *3rd.* New truth and its relation to Human progress: and *4th.* The Promotion of original Scientific Research. As the object of the book is only to call attention to the vast importance of *new* truth, as as a fundamental source of advance, and how to promote the discovery of it, the essay is written as briefly as possible, and is not offered in any sense as a complete exposition of the subject, especially the section relating to the Scientific basis of Morality.

The leading idea of the Book is that present knowledge only enables us to maintain our present state, that national *progress* is the result of *new* ideas, and that the chief source of new ideas is original research.[1] That as *advance* has its origin in *new* knowledge; unless new discoveries are made, new inventions and improvements must sooner or later cease. Another prominent idea is, that truth is essentially the same in all divisions of knowledge, and that the mental powers and processes employed in detecting it are the same in all subjects.

For reasons stated in the text, the influence of scientific discovery upon mental and moral progress are treated together. Notwithstanding the far greater importance of the mental and moral advantages of new truths, the book treats chiefly of the pecuniary and material gains to mankind; mainly because the latter are more easily understood and appreciated, the chapter however on "The Scientific Basis of Mental and Moral progress," indicates in a very brief and imperfect manner, the vast importance of new scientific knowledge to mankind, as a source of mental and moral advancement.

The chief object of this book is to disseminate more correct ideas respecting the importance of *new* positive knowledge, and the duties of society in relation to it; and a further object is to assist in maintaining Birmingham in the front rank of intellectual, social and moral advance, in accordance with its motto "Forward."

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[1] See p.p. 165 to 167.

CHAPTER I. The Scientific Basis of Material Progress

During the last one hundred years this nation has advanced with unexampled speed. More wealth has been accumulated by Englishmen since the commencement of the present century, than in all preceding time since the period of Julius Cæsar; one of the causes of this has been the discovery of new truths of science, and their subservience to useful purposes by means of invention. The great manufacturing success of this country has been largely due to those applications of science, which have enabled us to utilise our abundant stores of coal and iron-ore, in steam engines, machinery, and a multitude of mechanical, physical, and chemical processes; also to the discovery of electro-magnetism and its application in the electric-telegraph, etc. And had it not been for these and other adaptations of scientific knowledge, we should have competed in vain with the cheaper labour and longer days of toil of continental nations. Other great causes, such as our insular position, suitable climate, freedom, geographical position, etc., etc. have, however, also contributed to the result. Commerce also in its turn has done vast things for mankind.

The purely scientific knowledge we possess was discovered almost entirely by means of original research, and to only a small extent by persons engaged in industrial occupations. Probably not two per cent. of all the important discoveries in pure science were made in manufactories; the scientific experiments which are made in such establishments are usually of the nature of invention, not of discovery, and are not often published, because it is a usual object with men of business to retain as much as possible of the pecuniary benefit of their labours to themselves. Whilst it is the object of a business man to monopolise special knowledge; that of the scientific man is to diffuse it, in order that all mankind may be benefited and helped to improve.

Discoveries in science are, however, occasionally made by practical men engaged in technical employments. The hydro-electric machine originated in this way, a man at Newcastle was attending to a steam boiler, and found that he received electric shocks when he touched the boiler. This circumstance was investigated by his employer, Mr. Armstrong, a scientific man, and led him to construct the hydro-electric machine. The accumulation of electricity in submarine telegraph cables was first observed at the Gutta-Percha Company's works London. It was noticed on testing a cable by means of a voltaic battery (the cable being submerged in water) that discharges of electricity flowed from the cable after the battery was removed; this circumstance was investigated by Faraday, and led to improvements in submarine telegraphy. In each of these instances the same general method as that used by scientific discoverers was however employed, viz., new experiments were made (though not intentionally) by putting matter and its forces under new conditions, and new results were observed.

Nearly all great modern scientific discoveries have been made by teachers of science and others, who spend a large portion of their lives in experimental investigation, searching for new truths, and not by persons who have hit upon them by accident. The greatest discoveries in physics and chemistry in modern times, were made chiefly by such men as Newton, Cavendish, Scheele, Priestley, Oersted, Volta, Davy and Faraday: all great workers in science.

It is either by observing matter and its forces under new conditions or from a new aspect, that nearly all discoveries are made; thus Priestley placed some oxide of mercury in an inverted glass vessel, and heated it by means of the Sun's rays and a lens, and discovered Oxygen. This substance was nearly discovered by Eck de Sulsbach three hundred years before; he heated six pounds of an amalgam of silver and mercury, and converted the latter metal into a red oxide like cinnabar, and he remarked, "a spirit is united with the metal, and what proves it is this, that this artificial cinnabar submitted to distillation, disengages that spirit." The "spirit" was evidently oxygen.

Some discoveries are made by observing the phenomena of bodies placed under special conditions by those operations of nature over which we have little or no control. All our knowledge of Astronomy, and much of that of geology and physiology, was acquired in this way.

Nearly all modern discoveries of importance in physics or chemistry require long and difficult investigations to be made in order to completely establish their truth. When Crookes discovered Thallium, he saw the first sign of its existence in a momentary flash of green light in a spectroscope, but he had to expend upon the subject several years of most difficult labour, and a considerable sum of money, in order to prove the correctness of his suspicion that he had discovered a new metal. M. Lecocq de Boisbaudran discovered the metal Gallium and Bunsen discovered Rubidium and Caesium in a similar manner.

Discoveries in science, are usually made, not by trying to obtain some valuable commercial or technical result, but by making new, reliable, and systematic investigations. By investigating the chemical action of electricity upon saline bodies, Sir Humphrey Davy isolated sodium and magnesium, which has led to the establishment at Patricroft near Manchester, of the manufactures of those metals. By the abstract researches of Hofmann and others upon Coal-tar, many new compounds were discovered, and the extremely profitable manufacture of the splendid coal-tar dyes was originated.

Scientific discovery is the most valuable in its ultimate practical results when it is pursued from a love of truth as the ruling motive, and any attempt to make it more directly and quickly remunerative by trying to direct it to immediately practical objects, decreases the importance of its results, diminishes the spirit of inquiry, and sooner or later reduces it to the character of invention. The greatest practical realities of this age had their origin in a search after important truths entirely irrespective of what utilities they might lead to.

I do not intend by these remarks to imply that any new trades or improvements in manufactures have been or can be effected without the labours of inventors and practical men, but that there should be a more judicious division of labour: one man to discover new truths, another to put them into the form of practical inventions, and the business man to work them; because it is proved by experience, that in nearly all cases these different kinds of labour require men of widely different habits of mind, and that the faculties of discovery, invention, and practical working are very rarely united in one man.

Scientific investigations however, made in a manufactory, for the purpose of ascertaining the various sources of loss of materials, the circumstances which affect the amount or quality of the product; or made with the object of substituting cheaper or more suitable materials, or for varying their proportions, or for many other kindred objects, have in many cases resulted in great benefit to the manufacturer, and have formed the basis of successful patents. Some of the large brewers, chemical manufacturers, candle companies, and many others, constantly employ scientific men in this way to examine their materials, processes and products, and keep them acquainted with the progress of discovery and invention in relation to their own particular trades.

No art or manufacture is so perfect as to be exempt from the influence of discovery and invention, and no man can produce so perfect an article but that, by the aid of science, a better may be produced. Science and trade are mutually dependent, without the assistance of science, trade would be unable to supply our daily increasing wants, and without the pecuniary support of trade, science would languish and decay.

"As long as arts and manufactures are left to be directed and improved by simple experience, their progress is extremely slow, but directly scientific knowledge is successfully applied to them, they bound forward with astonishing speed." Look at the art of taking portraits; for hundreds of years it remained entirely in the hands of oil and water-colour painters with but little progress in rapidity of production, but directly science was applied to it in the form of photography, its advance in this respect became amazing. Fifty years ago photography was almost unknown, but immediately Messrs. Daguerre and Talbot, in 1844, made known their processes, the new art began to advance, and so rapid has been its progress, that at the present time many thousand persons are employed in its exercise, and millions of portraits have been taken with an accuracy and at a cost quite beyond the reach of the old method.

Many persons hardly know the difference between science and art; a still greater number cannot readily distinguish between a concrete science and a pure one; and nearly all persons confound discovery with invention. A science may be conveniently defined as a collection of facts and general principles which are to be learned; an art as a collection of rules which are to be followed: – Art therefore is applied science; and every art also has a basis in science, whether that basis has been discovered or not. Scientific principles underlie not only manufacturing processes, but also sculpture, music, poetry and painting.

Discoveries differ also from inventions: a scientific discovery is a newly found truth in science, which in the great majority of cases is not in the form of applied knowledge. An invention is usually a combination and application to some desired purpose, of scientific truths which have been previously discovered. When Oersted first observed a magnetic needle move by means of a current of electricity, he made a scientific discovery; but when Wheatstone and Cooke applied Oersted's discovery in their telegraph from Paddington to Slough, they made an invention. The success of the electro-plating process was dependent upon knowledge previously discovered. Mr. Wright, a surgeon in Birmingham, was led to the invention of the use of cyanide of potassium in electro-plating and gilding, by reading in Scheele's "Chemical Essay" (p.p. 405 and 406), that "if after these calces" (*i. e.*, the cyanides of gold and silver) "have been precipitated, a sufficient quantity of precipitating liquor be added, in order to redissolve them, the solution remains clear in the open air, and in this state the ærial acid" (*i. e.*, carbonic acid of the air) "does not reprecipitate the metallic calx."

Immediately a discovery is effected it is made public, and is afterwards incorporated in the ordinary text books of science, ready for the use of inventors; and in this way such books have become filled with valuable knowledge acquired by researches in past times. All this knowledge (which has cost millions of pounds and a vast amount of intellect and labour) has been given by its discoverers freely to the nation. Some idea of the number of scientific researches which have been made since the year 1800, may be obtained from the fact, that a mere list of their titles, with the names of the authors, occupies eight large quarto volumes, of about one thousand pages each, compiled and published at a cost of about ten thousand pounds, by the British Government and the Royal Society.

In discovery we search for new phenomena, their causes and relations; in invention we seek to produce new effects, or to produce known effects in an improved manner. The objects of the scientific discoverer are, new truth and greater accuracy; whereas those of the inventor, are increased usefulness and economy of results. The ancients classed inventors with the gods, because they considered them great benefactors to the human race. Discoverers may properly be viewed as priests and prophets of truth, because they both reveal new knowledge to mankind, and predict with certainty coming events.

A man cannot usually invent an improvement unless he possesses scientific knowledge, and, for that knowledge he must in nearly all cases resort to a scientific book or teacher. The great practical value of new scientific knowledge is proved by the fact, that when scientific discoveries are published, there are numerous inventors and practical men, who immediately endeavour to apply them to useful purposes. Since the first application of coal-tar to the production of dyes, every discovery in that branch of chemistry has been closely watched for a similar purpose.

A complete account of the growth and development of scientific discoveries and inventions would form an extensive history, and would include numerous instances of experiments attended by results which, sooner or later, affected all mankind. Take that of phosphorus, for example. The first evidence of the existence of that substance was obtained by the Saracens in the eighth century. Achild Bechil distilled a powdered mixture of charcoal, clay, lime, and dried extract of urine, and obtained a substance which shone in the dark "like a good moon;" that substance was phosphorus. The discovery contained in the results of that little dirty and stinking experiment was the germ or seed of all the subsequent developments and applications of phosphorus. About the year 1669 Bechil's experiment was further developed by Brandt, a merchant of Hamburg, and the publication of the wonderful properties of the substance produced a great sensation in his fellow-citizens. "There was then cried nothing but triumph and victory among the chymists. Those good people erected already in their thoughts so many hospitals and poor-houses that no beggar should more molest any man in the streets, made great legacies, and pious causes, and what not else." "Besides, the other alchymists did encourage him yet more, and desisted not to make him believe how this was the same fiery ghost of Moses that in the beginning moved upon the water, yea, his splendid shining face: the fiery pillar in the desert, that secret fire of the altar wherewith Moses burned the golden calf before he strewed it upon the fire and made it potable."

The experiment of Brandt was repeated by Kunckel before the courts of Saxony and Brandenburg, although it was not a very delicate or agreeable exhibition, "because the anctuous and daubing oyliness was not yet accurately separated from it, and without doubt it was very stinking." Brandt's process was further developed by Boyle, and published in the Philosophical Transactions of the Royal Society, in the year 1692-3; and phosphorus was afterwards obtained in larger quantity and in a purer state by Hanckwitz, a chemist in Southampton Street, Strand, and sold by him at three pounds sterling per ounce. Its price at present is less than three shillings per pound.

Margraaf, Fourcroy, Vauquelin, and Dr. Slare also extended our knowledge of the substance; Gahn, in 1769, made the important discovery of phosphorus in bones, and Scheele immediately devised the process now in use by our manufacturers for extracting it from that substance. The commencement of the use of phosphorus for the purpose of getting a light occurred about the year 1803, but it was not until the year 1833 that the invention of phosphorus matches became commercially successful. The use of such matches is now universal, and it has been estimated that the daily consumption of them in Great Britain alone amounts to two hundred and fifty millions, or more than eight matches per day for each individual in the kingdom.

"There is nothing on the Earth so small that it may not produce great things." The most abstract and apparently trivial experiments in original research have in some cases led to inventions and results of national and even world-wide importance. The contractions of a frog's leg in the experiments of Galvani, and the movements of a magnetic needle in those of Oersted, have already led to the expenditure of hundreds of millions of pounds in laying telegraph wires all over the earth, and to an immense extension of international intercourse. But the original experiment of Oersted was not discovered without labour, it was only arrived at after many years of research.

The saying that "all great things have had small beginnings," is true, not only of electric telegraphs, but also of the great trade of electro-plating, and of the magneto-electric machine which is now largely used instead of the voltaic battery. After Volta had made his small and apparently unimportant experiments on the electricity produced by metals and liquids, various persons tried the effect of that electricity upon metallic solutions. Brugnatelli, in 1805, found that two silver medals became gilded in a solution of gold by passing the electricity through them. Mr. Henry Bessemer, in 1834, coated various lead ornaments with copper by using a solution of copper in a similar manner. And in 1836 Mr. De la Rue found that copies might be taken in copper of engraved copper-plates by the electro-depositing process. Faraday discovered magneto-electricity in the year 1831, by rotating a disc of copper between the poles of a magnet, and he has stated that the first successful result he obtained was so small that he could hardly detect it. This simple experiment was the origin of the magneto-electric machine, and many of these machines are now used for producing the electric light, and for depositing nickel, copper, silver, and gold, instead of by the voltaic battery. These, and other engines, thermic, magnetic, electric, &c, will probably, ere long, be constructed on as large a scale, and as many in number, as the present steam engine.

The discovery in olden times of the attractive properties of a fragment of iron ore, was the basis of the invention of the mariner's compass, which greatly improved navigation, and led to nearly all the chief maritime discoveries which have since been made. The sciences of magnetism and geometry form the basis of the art of navigation, and have thus made our great foreign commerce possible. The discovery of magnetism enabled sailing vessels to venture freely out of sight of land, and to traverse the wide ocean with even greater safety than to sail near the shore. By its means Columbus crossed the Atlantic Ocean and discovered America. By its means also, Vasco de Gama sailed round the Cape of Good Hope and discovered a new route to India; and in the year 1500, another Portuguese Captain, Cabral, was driven across the Atlantic, discovered Brazil, and was enabled by the aid of the magnet, to send back a ship to Lisbon with news of the discovery. By its assistance also Magellan discovered Patagonia and the South Pacific Ocean; and by the completion of that voyage the Earth was first circumnavigated and proved to be a globe.

The geographical discoveries of the Portuguese, made by means of the magnet, produced great national results; they profoundly changed the balance of power and wealth among European nations, by changing the direction of navigation and of the great streams of commerce between Europe and the East. They gave a mortal blow to Italy and the cities of the Mediterranean, by transferring Eastern commerce to Spain and Portugal: and Egypt ceased to be the greatest route of commerce from Europe to India.

A singular contract relating to geographical research was made in the fifteenth century, between King Alphonso, of Portugal, and Ferdinand Gomez, of Lisbon, by which the latter engaged to navigate a ship and explore the coast of Africa, and to discover not less than three hundred miles of coast every year, the measurement to be made from Sierra Leone.

Scientific discovery has in all ages been a most powerful agent of civilization and human progress. The discovery of the black liquid which a solution of nutgalls produces when mixed with green vitriol, led to the invention of writing ink; and a knowledge of the properties of ink and paper prepared the way for the invention of printing, by means of which truth and learning have spread all over the earth.

The apparently insignificant property possessed by amber, of attracting feathers immediately after it has been rubbed, was known twenty-four hundred years ago, and afterwards led to the discovery of electricity. In later times, Dr. Franklin, by means of a kite, charged a bottle with lightning, examined it, and proved lightning and electricity to be identical. This knowledge, joined to the further discovery, that electricity would pass freely through metals, led to the modern invention of the lightning conductor, by means of which all our great buildings, ships, lighthouses, arsenals, and powder magazines are protected from lightning.

"Coming events cast their shadows before them: " the discovery of the instant transmission of electricity along wires by Stephen Gray and Wheeler, about the year 1729, fore-shadowed the invention of the electric telegraph. About the year 1819, Oersted, a Danish philosopher, after fifteen years of study and experiment, to ascertain the relation of electricity to magnetism, discovered that if a freely suspended magnetic needle was supported parallel and near to a wire, and an electric current then passed through the wire, the needle moved and placed itself at right angles to the current. This discovery, coupled with the previous one of the electric conductivity of metals, formed the indispensable basis of all our electric telegraphs.

Original research is very productive of new industries and inventions. The discoveries made by Volta, Faraday, and many other investigators, have led to the process of electro-plating, the use of electric lights for lighthouses, and for ocean steamships, and the great system of telegraphs. Those of Davy, Wedgwood, and others, respecting the action of light upon salts of silver, have resulted in the modern processes of photography, which are now in use almost everywhere. The discovery of zinc, by Paracelsus, has been followed by the use of that metal in galvanic batteries, and the great use of "galvanized" iron for telegraph wires, for roofing, and many other purposes. The discovery of nickel, by Cronstedt, has led to the great modern use of that metal in electro-plating, and to that of German silver in the construction of electro-plated and other articles. The discovery of chlorine, by

Scheele, formed the basis of nearly all our modern processes of bleaching cotton and other fabrics. The discovery of gun-cotton and nitro-glycerine has led to the use of those substances in blasting rocks and in warfare. The discovery of oxygen, by Priestley, has enabled us to understand and improve in a great number of ways the numerous manufacturing, agricultural, and other processes in which that substance operates. Priestley made many experiments also on the absorption of gases by water, and proposed the resulting liquids as beverages; and those apparently trifling experiments have since expanded into the large manufactures of aërated waters. The discoveries of gutta-percha and india-rubber were indispensible to the great applications of those substances in telegraph cables, and in a multitude of useful articles. The discovery of chloroform and anæsthetics has led to their use for the purpose of alleviating human suffering. The discovery, by Sir Isaac Newton, of the decomposition of light by means of a prism, has led in recent times to the invention of the spectroscope; to the use of that instrument in the Bessemer steel process; to the discovery of a number of new metals, thallium, rubidium, cæsium, indium, and several others, and to the most wonderful discovery of the composition of the Sun and distant heavenly bodies.

Even the invention of the steam-engine was partly a consequence of previous researches made by scientific discoverers. Watt, himself, stated in his pamphlet, entitled "A plain Story," that he could not have perfected his engine had not Dr. Black and others previously discovered what amount of heat was rendered latent by the conversion of water into steam. "Each mechanical advance in the steam-engine has been preceded by and the result of the discovery of some physical law or property of steam." "The first step in the invention of the steam-engine was the experimental research and the discoveries of the properties of steam by Hooke, Boyle, and Papin."[2] Had not the steam-engine been developed, it is clear that railways, steamships, machinery, and all the other numerous uses to which that instrument is now applied, would have been almost unknown. The introduction of the steam-engine enabled abandoned Cornish mines to be relieved of water, and to be worked to much greater depths. The discoveries of nitric acid, hydrochloric acid, oil of vitriol, and washing soda, by the alchemists and early chemists in their researches, led to the erection of the numerous great manufactories of those substances which now exist in England and in other civilized countries. There is probably not an art, manufacture, or process, which is not largely due to scientific discovery, and if we trace them back to their source we nearly always find them originate in scientific research.

So far has scientific discovery, and its practical applications to human benefit by invention, now progressed, that every one considers this to be, *par excellence*, the scientific age. And as discovery and invention continue to progress with accelerated speed, we are encouraged to hope, not only that scientific principles will ultimately be universally recognised as the regulators of all technical industry, but also as a fundamental basis of morality.[3]

"It is true that some processes of manufacture have not been consequences of abstract scientific discovery – that they originally resulted from alterations made in the rudest appliances, and that they have been directed and improved by the results of simple experience. For ages past we derived the benefit of scientific principles without a knowledge of their existence. We trod in the beaten paths of experience ignorant of the truth that we were acting in unison with fixed and certain laws. Numerous arts and processes were in extensive operation long before the principles involved in them were at all understood. The arts of enamelling and of iron smelting were known hundreds of years before we were acquainted with the principles of chemistry. In some rare instances also the recorded results of daily experience in practical matters, tabulated and studied, have ultimately led to the discovery of scientific laws; but all this is merely the making use of our ordinary experience for the advancement of knowledge, instead of making *special experiments* for the purpose."

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[2] Essays and Addresses, Owen's College, 1874, pp. 172-182.

[3] See Chapter 2, Section B.

Many of our processes and manufactures, those of glass and copper for example, are of such great antiquity, it is impossible to ascertain with certainty the special circumstances under which they originated; but after we have fully considered the ways in which various modern trades and manufactures have first arisen, we shall come to the conclusion that all manufactures and improvements in manufacturing processes, must have been first produced by the same general means, viz., new observations, although the special circumstances connected with the origin of each were different.

Let us consider German-silver and its manufacture. That substance is an alloy of copper, zinc, and nickel; it owes its peculiar whiteness or "silver-like" appearance to the latter metal, and cannot be made without it; it is certain, therefore, that by whatever means that metal or the alloy was discovered, the discovery was the origin of the German-silver manufacture, and was essential to all manufactures, processes, or appliances in which German-silver, nickel, or any of its compounds are used. Nickel was discovered by Cronstedt during the year 1751, and its compounds were chiefly investigated by English and foreign chemists. Cronstedt found it as a peculiar metal in the mineral called kupfernickel, whilst chemically examining the properties of that substance. The general method by which he discovered it was careful experiment, observation, and study of the properties of matter.

It is stated that the Chinese and other nations made alloys of nickel long before nickel itself was known to be a distinct metal; they had found, by experiment, that when ores of copper and zinc were mixed with a particular kind of mineral and smelted, a white alloy was obtained; but this also proves the general statement already made, that the German-silver manufacture was originated by means of new observations. It was by a more skilful, but similar mode of procedure that Cronstedt isolated the metal itself, and thus laid a definite basis of improvements in the manufacture of its alloys.

No art is probably more antique, or remained longer exempt from the influence of science, than that of match making and obtaining a light. Many adult persons can remember the primitive and old-fashioned tinder-box, which had passed, with its flint and steel, from one generation to another without any material improvement. Phosphorus, it is true, was definitely discovered at least as early as the year 1669, but it was not applied to match making till about 1833. Since then the progress of invention has been so rapid that there are now numerous manufactories which produce many millions per day of phosphorus matches; for instance, those of M. Pollak, at Vienna, and of M. Fürth, in Bohemia, consume together more than 20 tons of phosphorus annually, and give employment to about 6,000 persons, and as one pound of phosphorus suffices for about one million German matches (or 600,000 English ones), those two makers alone produce the astonishing number of 44,800 millions of matches yearly.

Judging by means of the experience already acquired, we cannot reasonably expect that discoveries fraught with such momentous consequences as those of magnetism or of galvanism and electro-magnetism, will be made very often. The progress of scientific discovery is gradual; we have at present but mere glimpses of the new world of truth which is being revealed to us by means of research; we are only at the very commencement of a knowledge of the inherent properties of matter and its forces, and consequently the methods we employ to utilize them are extremely imperfect. Matter has a general property of subdividing and transmuting forces; if we apply one force to a substance or machine, it produces many effects, not only those we want, but those also we do not want; when we heat a piece of iron, the heat produces a number of changes, mechanical, electric, magnetic, and chemical, and it is partly by means of what is termed the "internal resistance" of bodies that these effects are produced, and we know but little of that property. The explosive action in a gas engine produces not only the mechanical force we desire, but also a quantity of heat we do not want, and at a cost of a portion of the gas. In a similar manner, in the steam-engine the largest portion of the heat of the coal is converted into forces which are lost; a large amount of it is uselessly expended in warming the machine itself and the surrounding atmosphere; much also is lost by friction.

That "knowledge is power" is an old maxim, but that *new knowledge is new power* is a new maxim which scientific discovery has impressed upon us. By means of discoveries we have acquired new powers; by those of electricity we have acquired the ability of conversing with each other at unlimited distances, and by means of those in optics we are enabled to analyse the composition, and perceive some of the physical changes of the most distant heavenly bodies. As our ignorance is probably much greater than our knowledge, more inventions also, and extensions of human power, must ultimately result from discovering new qualities of bodies, than by applying to useful purposes their already known properties.

Experience in science has already shown that it is by means of invention based upon *new* discoveries that the greatest utilities are obtained, rather than by the exercise of invention upon knowledge acquired long ago. The information obtained by research in former times has been largely exhausted for the purposes of invention by modern inventors, and what we very greatly require now is *new* knowledge. Experience in science also leads us to believe that the extent of possible discovery is as boundless as Nature, and that an immense amount of new knowledge may yet be discovered. Every discoverer of repute could supply a copious list of investigations yet to be made.

An infinite number of questions in pure science remain to be decided by means of research. Is Electricity decomposible like radiant heat or light? Are the "elementary substances" really compound bodies? Are they all compounds of Hydrogen? Are they all decomposed by very high temperatures, as compound substances are "disassociated" by less elevated temperatures? Under what conditions is Fluorine isolated? Do gases transmit heat by conduction? Under what circumstances is Light converted into Electricity? and into Magnetism? What is the actual size of an atom of Hydrogen? Does Light (without heat) expand bodies? What is the actual molecular arrangement of the atoms of Hydrogen at 60 Fahrenheit? What is the cause of the absence of metalloids in the Sun? What are the properties of Fluorine? What is the vapour density of Cæsium? Under what circumstances is heat wholly converted into mechanical power? &c., &c. All these discoveries when made, will probably, sooner or later, be productive of practical benefits to mankind.

Nearly every manufacturer in this country is deriving, from scientific discoveries, advantages for which there has been little or no payment made to the discoverers. The makers of coal-tar-dyes, and dyers of wool and silk, are using Mitscherlich's discovery of nitro-benzine. Manufacturers of picric acid and "French purple" have enjoyed the fruits of the labours of Dr. Stenhouse. Makers of chlorate of potash and cyanide of potassium are profiting largely by the discoveries of Scheele, Gay-Lussac, and others. All the percussion cap makers are indebted to Howard and Brugnatelli for fulminating silver. Railway-contractors, quarry-proprietors, and others, use nitro-glycerine discovered by Sobrero. Iron smelters are benefiting by the discovery of Bunsen, that 42 per cent. of the heat of the fuel was lost as combustible gases – these gases are now utilized. Telegraphists and electro-platers are also indebted to him for his voltaic battery. The producers of metallic magnesium owe the origin of their process to him as being the first to convert it into wire and make known its great light giving power. Multitudes of persons now use his well-known "Bunsen's burner" for heating, cooking, and other operations. The various telegraph companies, copper smelters, and makers of copper telegraph wire, are using Dr. Matthiessen's discovery of the influence of impurities on the electric conducting power of copper. Phosphorus-makers are reaping the reward of the labours of Gahn and Scheele. The makers of electro-plate and German silver are deriving profits from the labours of Faraday, who investigated electrolysis; of Gay Lussac, who discovered cyanogen; and of Cronstedt, who discovered nickel. Makers of Bessemer steel enjoy advantages derived from the spectrum discoveries of Kirchoff. Iron and copper smelters, metallurgists in general, dyers, calico printers, bleachers, brewers, makers of vinegar, red lead, varnishes, colours, soaps, green vitriol, phosphorus, oil-of-vitriol, and many others, are deriving benefit from the discoveries of Priestley and Scheele. Physicians and their patients are receiving the reward of the labours of Soubeiran, Liebig, and Dumas, in the discovery of chloroform; of the researches of Fourcroy, Vauquelin, Pelletier, and others, in the discovery of quinine; and of many other chemists who discovered numerous remedial substances. By means of the discoveries of Oersted and others, embodied in the telegraph, manufacturers are enabled to anticipate the state of the markets and of the weather, and editors are enabled to obtain the earliest news.

Suppose that Gay Lussac, in 1815, had not discovered cyanide of potassium, and that it had never been discovered, it is highly probable that the manufacturing returns of Birmingham and Sheffield would be much less in amount at the present time than they are, simply because there is no other known substance with which the electro-plating of base metals with gold and silver can be satisfactorily effected. Or suppose that sal-ammoniac, chloride of zinc, or other soldering agents had not been discovered, the extensive and so-called "galvanizing" process could not have been effected, because without those substances the iron articles immersed in the melted zinc would not have received an adhesive metallic coating.

On the other hand, science has in various cases rendered obsolete some manufactures and superseded old customs, comforts and conveniences. We have ceased, or almost so, to use tinder-boxes, snuffers, sulphur matches, rush-lights, tallow candles, sedan chairs, stage coaches, the ancient water-bucket and well, and even the comparatively modern pump; coal fires also are gradually being superseded by fires of gas, and articles formed of solid silver are now being replaced by those of electro-plate; canals have also to some extent been supplanted by railways. But in all these cases science has supplied us either with something better or more suited to our present wants.

The great pecuniary benefits arising from the applications of science are generally reaped in the first instance by the great manufacturers, agriculturists, merchants, and capitalists. Countless fortunes have been made by means of processes and manufactures based upon scientific discovery. The pecuniary benefits of calico printing, bleaching, dyeing; of the great manufactures of cotton, iron, pottery, beer, sugar, glass, spirits, vinegar, gutta-percha, india-rubber, gun cotton, the numerous metals, machinery, electro-plate, washing soda, German silver, brass, phosphorus, manures, the common acids, numerous chemicals, and a multitude of other substances and articles, have been extremely great. More than eighteen hundred million pounds of sulphuric acid alone are manufactured in Europe yearly. The pecuniary advantages of the use of the electric telegraph and railways to merchants, the gains of capitalists by monies invested in railways, telegraphs, steam-ships, cotton-mills, gas-works, iron shipbuilding, engineering, and other great applications of science, have been enormous. The annual gas rental of London alone amounts to more than two millions sterling; and even in Birmingham the produce of gas is more than twenty-five hundred millions of cubic feet yearly. The amount of capital expended in the construction of railways only in this country, has been estimated at more than seven hundred millions of pounds, and the total receipts upon British railways has reached forty-three millions per annum. In the year 1875 our railways carried 200 million tons of goods, and consumed ten million tons of coal; the Great Northern Railway alone consumes 5,000 tons of coal each week. In the year 1877 there existed in the entire world about 198,000 miles of railway, the whole having been constructed since the year 1825. In the year 1880 six hundred millions of journeys were made by passengers on British railways; and the stock of those railways included 13,174 locomotives; 369,694 waggons, 28,717 passenger carriages, and 22,712 other vehicles. The London and North-Western Railway Company alone possessed, in the year 1873, no less than 1,900 locomotive engines, each of a value of nearly two thousand pounds; 4,000 carriages and 36,000 waggons; and it has been estimated by competent authorities, that there are in the world 200,000 steam-engines, having a total power of twelve million horses, or 100 million men. The number of cotton spindles on the whole Earth is estimated at about 71¼ millions. In the United States of America there are about five thousand telegraph stations, and 75,000 miles of line, which transmit yearly about 11,500,000 messages. – The telegrams of Great Britain number about one-fourth of a million per week. The world's telegrams during the year 1877 numbered nearly 130 millions; and the world's letters about 3,300 millions, or 9¼ millions each day. Even the little phosphorus match is being manufactured and consumed at a rate estimated at more than ten thousand millions daily.

Much of the wealth of this country, resulting from science, has been very easily obtained by its possessors. That acquired by means of our coal has especially been obtained without commensurate effort. The amount of that substance raised in Great Britain during the year 1876 was 734 millions of tons. To draw upon a great stock of that mineral is like drawing money from a bank, because coal, unlike any other abundant substance (except wood and petroline), contains in itself an immense store of energy, which is evolved as heat during combustion, and may be utilized. Each piece of coal contains sufficient energy to lift its own weight twenty-three hundred miles, but it costs only a small proportion of that power to extract and raise it from the mine. I do not mean by these remarks to imply that the wealth accruing from this great store of power in coal is derived chiefly by the owners of coal mines.

This acquisition of wealth without commensurate sacrifice is not an unqualified advantage; it constitutes a debt to nature, which upon the great principle of causation, and of equivalency of action and reaction, must sooner or later be repaid. Judging from the infallibility of the action of those laws, and the signs of the times, this nation is now beginning to repay in the form of emigration of trade to other lands, and of relatively less rapid national advance, the debt incurred by undue pecuniary success. An excess of money or power obtained without equivalent effort, fails to properly develop the intelligence of its possessors, and nations have been hastened to ruin in this way. Our great success in getting money has attracted many from the pursuit of knowledge, and our love of knowledge has not increased as fast as our wealth. The wealth of the upper classes has, by decoying from study undisciplined young men at our old Universities, kept down the general standard of scientific instruction throughout the country, and, by leading to neglect of scientific research, is now retarding our progress in arts, manufactures, commerce, and civilization. The consequent relative poverty of the working classes is also producing similar effects by retarding education, and contributing towards the great deficiency of skilled labour, of which our inventors, manufacturers, and others so strongly complain in the working of their scientific processes. Had a just share of the great amount of money, gained by the application of science to useful purposes, been applied to the payment and maintenance of scientific discoverers and inventors, as it should have been, the general standard of scientific education would have been higher, the poor would have had more employment and money, and the happiness and civilization of all would have been greater.

In a usual way the greatest pecuniary benefits, arising from science, sooner or later go to enrich the possessors of land. The demand created for coal, iron, lime, building-stone, and all the metals, by the industrial applications of science, has greatly increased the value of land under which those substances lie. The value of cultivated land has been everywhere increased by the discoveries of agricultural chemistry. Land has also been required for railways in nearly all parts of the kingdom, and has thereby been considerably raised in value. Discoveries produce inventions, inventions give rise to processes and manufactures, the employment of workmen and others, and the erection of workshops and dwellings, and these have rapidly increased the value of building ground. In Lancashire the value of such ground has been greatly increased by the inventions of the steam-engine and machinery, the discovery of chlorine, and their application to cotton manufacture. In all the great manufacturing districts, and in all the chief centres of industry, a similar result has occurred. Wherever a railway has been constructed, the value of land has also increased in consequence of the increased facilities of communication. All these great additions to the value of land are largely due to the unpaid labours of scientific discoverers, and it may be said that this nation has largely gained its wealth, and is still living in a great degree on the products of those labours. Those great additions to the value of land are also permanent, are continually increasing, and are largely independent of any exertions on the part of the owners. That many other influences, besides that of science, have contributed to the development of our manufacturing and commercial prosperity is also true, but it would be foreign to the subject of the present chapter to point them out.

It is a fallacious argument to say that scientific discovery and increased value of land are only remotely connected together, a cause as certainly produces its effect, however many connections lie between them, provided the connections are certain – the number of links in a chain makes no difference in the transmission of motion from one end of it to the other. Great causes are frequently distant and wide-spread in their effects. Persons in general can easily understand that an acorn planted in the ground will in the course of time become an oak, because it is a palpable and visible effect; but they cannot so readily perceive that the benefits resulting from a knowledge of science ramify through all our manufacturing, artistic, and commercial occupations, our social and moral relations, and our every-day life, not because the dependence of our welfare upon science is less real, but partly because the connection between the two is less understood.

Not only has science benefited manufacturers, but also operatives, because the extension of science to manufacturing purposes has compelled them to make themselves acquainted with intellectual subjects. "Instead of remaining mere machines, mechanically performing the work set before them, they are obliged to exercise the faculties of observation and judgment in watching the results and directing the action of mechanical, physical, and chemical powers. Instead of following the blind path of experience, using unknown forces to accomplish some definite result, they pursue their labours with the aid of known and certain laws." It is true that in many cases artisans who have acquired a little knowledge of science have thereby been rendered conceited and unfit for their special employment, and this has made many manufacturers object to technical scientific education for their servants; but this would not be so much the case if scientific knowledge were more generally and equally diffused. Arguments are not unfrequently adduced to support the opinion that ignorance has its advantages; but, however great the advantages of ignorance may be, those of knowledge are greater.

In consequence of the labours of scientific discoverers and inventors, the progress of science is such that in a very few years a knowledge of it will be indispensible to all persons engaged in superintending or carrying out manufacturing operations, and in all arts, occupations and appointments in which man is dealing with matter. Science is fast penetrating into all our manufactures and occupations, and "those who are unscientific will have much less employment and will be left behind in the race of life." England also will be compelled, by the necessities of human progress and the advance of foreign intellect, to determine and recognize the proper value of scientific research as a basis of progress. National superiority can only be maintained by being first in the race, and not by buying inventions of other nations.

The philosophy of matter is the foundation of all manufacturing arts and artistic processes; technical education, or the relation of science to manufactures, &c., can only be properly imparted upon the basis of a sufficient knowledge of theoretical science. Science tends to abbreviate mental and bodily labour. The use of our reason saves us the labour of using our senses, because it enables us to know that under certain conditions a certain effect must occur. The use of our reason and senses also saves us using our hands.

The properties of a single substance are so numerous that if a workman was to thoroughly study the whole of them, he would become a scientific authority in the subjects of heat, light, electricity, magnetism, and chemistry. A blacksmith who knew all the physical and chemical properties and relations of iron and steel would be quite a scientific philosopher.

No man has more occasion to bless the introduction of the steam-engine, machinery, the galvanic battery, and science in general, than the working mechanic, because it has mitigated his physical toil by giving him the duty of simply directing the labour instead of actually performing it; whilst it has deprived him of one kind of employment it has provided him with something better. But a few years ago the operatives in the silver-plating trade had to lay the silver on the articles with their hands, with the aid of a soldering iron; now they have simply to set their batteries in action and watch the electricity doing it for them. In a similar manner the working engineer at his metal-turning lathe has merely to direct the action of his tools whilst the steam-engine performs the heavy labour of turning.

There is not a man in this kingdom who has not derived some advantage, in one way or another, from scientific research. The advantages of gas light, electric light, rapid postal service and transmission of goods, railway travelling, steam-ships for navigation, cotton apparel, photography, cheap pottery, improved medicine and surgery, telegraphic forecasts of weather, Australian preserved meats, &c., &c., have been reaped more or less by everyone, even the very paupers. Not only has travelling been considerably cheapened and immensely increased, but also rendered more safe: – in travelling by diligence in France the average number of persons injured was 1 to every 30,000 carried; and killed, 1 in every 335,000; but by railway, notwithstanding the average length of the journey has greatly increased, the former has been diminished to 1 in 580,000, and the latter to one in five millions; safety in travelling by sea has also been greatly increased by means of improved lighthouses. By the rapid transmission of messages by telegraphs and of commodities by steam-ships and railways, the horrors of famine have been largely diminished; the health of this nation has also been improved by greater variety of foods, and the increasing cost of meat has been restrained. It is well known that in periods of famine, the great loss of life has arisen, not from universal scarcity of food, but from the loss of time in ordering and conveying it. Whilst also the steam-engine has been the means of relieving hundreds of thousands of men from mere animal toil; it has, with the aid of the printing-press, supplied them with cheap daily intelligence.

Science has also proved itself to be a great source of employment, as well as wealth. By developing new processes it has given employment to whole armies of workmen in numerous arts, manufactures, and occupations. Some of those employments necessitating scientific training. About 300,000 persons are employed on railways alone in Great Britain, besides those who were engaged in their construction; and in the postal department alone of the telegraph service of this country more than fifteen thousand operatives are employed. Chemical works also find employment for twenty-six thousand, and gasworks for ten thousand work people. The telegraphs of the United States of America alone, provide employment for about 7,000 persons; and the railways of the world employ about 1,900,000 men.

It may be objected that the extension of science in this country, instead of increasing employment for workmen has produced an opposite effect, by so increasing the production of goods by machinery, and by physical and chemical processes, that we have glutted the markets of the world in years gone by, and are now suffering the results of over-production. This is a very limited view of the case; over-production is only true of particular manufactures, and is a result of ill-directed commercial energy, to which manufacturing skill is only a servant. The objection also contains its own reply; – that it is certainly much greater to our advantage to have supplied other nations with manufactured commodities, than that other nations should have supplied us, as they would have done had they the manufacturing skill. At present, however, continental nations are gradually supplanting us in manufactures; and gradually supplying us with the goods which we formerly supplied them, and our fear is that this is largely a result of our neglect of science.

In many cases instead of superseding labour, science has changed its kind, or its mode of distribution; – in the case of steam-ships, instead of navigation being conducted entirely by nautical ability, it is partly effected by the skill of the engineer; conveyance of goods by road and canal has not been entirely supplanted, but partly supplemented by conveyance by railways. The diminution of labour which sometimes occurs in consequence of the progress of science is extremely small compared with its increase. The number of waggoners and horses now employed, merely to collect and deliver all the goods for railways, is actually much greater than the whole of those employed for conveying all the goods of the country before railways were constructed.

It would be altogether a false argument to say that the practical benefits derived from the labour of scientific discoverers by the different classes of the community are uncertain or imaginary, because the discoveries and the practical benefits are not in all cases immediately connected. We know that the consumers of tea in this country derive benefit from the grower of that herb in China through the hands of a series of intervening agents, as certainly as if they received the tea direct from his hands. Cause and effect are inseparable, and the remote effect of a series of connected causes is not less certain than the immediate ones.

It is a remarkable fact, that of the multitude of rich manufacturers, merchants, capitalists, and land-owners in this country, who have derived such great pecuniary benefits from original scientific research, there is scarcely one who has ever given to a scientific society, institution, or investigator, a single thousand pounds for the aid of pure research in experimental physics or chemistry;[4] the nearest approach to exceptions are a very few wealthy persons who have devoted themselves personally to scientific discovery. Manufacturers have willingly reaped the advantages of the labours of unpaid discoverers, but have not adequately sowed the means of future progress. Many of those manufacturers and others would, however, willingly give money towards such an object if they understood the value and the necessity of scientific research.

Whilst also many millions of pounds are annually expended in this country upon religious, philanthropic and other good objects, there is scarcely a scientific society or institution (with the exception of the Royal Society and the British Association) which expends even the small sum of five hundred pounds a year on pure experimental research in physics or chemistry. In the Royal Institution of Great Britain, the average annual expenses relating to experimental research, including salaries to assistants for research in the laboratory, from the year 1867 to 1871, did not amount to two hundred and fifty pounds. On the other hand, the "total net receipts" of the British and Foreign Bible Society alone, amount to about £213,000 a year. These circumstances strongly indicate extreme ignorance of the value and necessity of new scientific knowledge, and an equally strong desire to aid any good object which is understood. The money given to charitable and religious objects is largely a result of the unpaid labours of scientific investigators in the manner already described. The fact that verifiable truth is seriously neglected, whilst millions of pounds are annually devoted in this country to the support of dogmas and doctrines, proves that the English nation is even now in a very imperfectly civilized state.

Considering the multiplicity and variety of philanthropic institutions and bequests in this country, and the great effect original scientific research has in ameliorating the condition of mankind, and reducing the amount of human misery, it is surprising that no wealthy philanthropic individual has bequeathed funds for the endowment of an institution for pure research in physics or chemistry.[5] In America, the Smithsonian Institution was founded at Washington by benevolent and patriotic persons,[6] "for the increase and diffusion of knowledge among men," and one of the objects of that institution is "to enlarge the existing stock of knowledge by the addition of new truths," and a portion of its plan is "to stimulate men of talent to make original researches by offering suitable rewards for memoirs containing new truths," and "to appropriate annually a portion of the income for particular researches."

What is the reason that scientific research is not sufficiently encouraged in England? It is chiefly ignorance. There are very few good and important subjects, understood by the public, which are not

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[4] In the year 1870, a gentleman of the name of Davis bequeathed £2,000 to the Royal Institution, London, to aid original scientific research.

[5] As a notable exception to the above statement: – "Scientific research has now an Institute of its own in Birmingham, without being indebted to the public funds. A fund has already been collected for carrying on the work. The building is called 'The Institute of Scientific Research.'" See *Nature*, January 7th, 1881, p. 366; the *Athenæum*, February 5th, 1881, p. 204; the *English Mechanic*, p. 537, February 11th, 1881.

[6] Professor Bache left 50,000 dollars, and Smithson bequeathed 541,000 dollars to this Institution.

in this country greatly assisted, nor many valuable public servants, whose labours are understood, who do not receive liberal payment and reward; and scientific research and discoverers therefore are neglected, not wilfully, nor because persons are unwilling to encourage good objects, but because scientific discovery and its great value to the nation are so little known. Scarcely a member of our legislature, or of our Universities, is fully acquainted with the national importance of scientific discovery,[7] and it would probably be impossible to find a subject of such great magnitude so little understood. Comparatively few persons have clear ideas of the essential differences between scientific instruction and research.

Scientific research can only be successfully pursued by employing the highest motive – viz., a love of truth in preference to all things; and this is a condition which very few persons really understand, and a principle which a still smaller number practise. Men in this country are so accustomed to be actuated by the less noble motive of immediate self-interest or of some apparent practical result, that they cannot perceive that in scientific investigation the most valuable results can only be obtained by employing the highest motive. However necessary and effective the motive of immediate self-interest or of apparent practical result may be in ordinary affairs of life, it will not enable a man to make many discoveries, because it leads him away from those which are possible to search for others which may or may not be possible. The beginning of discoveries are often so very small, that it requires acute senses and observation in order to perceive them; and if the mind is preoccupied with a desire to discover some particular practical object, new phenomena are overlooked. In discovery, man must follow where Nature leads.

Another cause of want of encouragement of research, is the natural selfishness which exists, though in very different degrees, in all men. Many wealthy persons wish things to remain as they are. Some manufacturers would not aid research unless they could monopolize its advantages. Students also generally prefer those subjects which are best rewarded, and do not sufficiently consider their intrinsic value. The love of truth for truth's sake alone is very weak in most men, and but few men make the greatest good their chief object in life.

The extreme ignorance in this country of the value of scientific research, is also largely due to the narrowness of the "practical" character of the English mind; men cannot perceive the deep-seated and universal sources of their wealth, and they prefer those occupations which yield the most obviously remunerative results. It is also partly due to scientific investigators themselves not having pleaded their own cause; such men have been so absorbed in the more important occupation of discovery, that they have, probably more than any other class of persons, neglected to enforce the just claims of their own subject. It is, however, chiefly caused by the influence of misapplied wealth, operating through the old Universities and large public schools. The sons of the wealthy are most of them educated at those institutions, and according to evidence supplied by University authorities to Royal Commissioners, many persons send their sons to those places for other purposes than to acquire learning, and allow them too much money. The considerable wealth of these young men supplies them with attractions which decoy them from industrious study, and the wishes of the parents and students have been largely acquiesced in by the tutors and college authorities. At our old Universities also, physical and chemical knowledge is very much less rewarded than some other subjects, though latterly a considerable improvement has been made in this respect, but even now there is not a University in the kingdom in which a knowledge in scientific research is necessary in order to obtain the highest scientific honour.[8] In these various ways physical and chemical science has been kept very low in our chief seats of learning; and scientific research is greatly neglected by the governing authorities.

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[7] Respecting the Members of our Houses of Legislature, a former Postmaster-General remarked to me, that a dose of scientific research would be too much for them.

[8] The Victoria University has recently become a partial exception to this statement.

It is reasonable to suppose that Universities should be fountains of new theoretical scientific knowledge, as well as be the disseminators of it, and that they (especially the old ones with their rich endowments) would be certain to promote scientific research, as being especially a part of their functions; but such is not the case. Our old Universities have not established any professorships of original research; they make no payment for such labour, nor reimburse any expenditure incurred in such occupation, and afford but little facility for the prosecution of pure scientific inquiry. Further, they discourage scientific discovery by giving the greatest emoluments, and the highest honours in science they have to bestow, to young men who have never made a single original research, or discovered a new fact in science. The money paid in the form of comparatively sinecure fellowships, or retiring pensions to young men in Oxford alone, "now amounts to about eighty or ninety thousand pounds a year." It may be objected that young men are not capable of doing original research, but as they do it in German Universities, they can also do it in England, if they are properly disciplined, and are not decoyed from industry by the possession or expectation of wealth. A man who has never made a scientific research is not the most worthy recipient of the highest scientific honours, and in Germany it would not be given to him; he is not properly disciplined in the detection of error or the discernment of truth in matters of science; he is deficient in accuracy of scientific judgment, and in the true spirit of scientific inquiry.

It is unnecessary to speak of what has been done during the last few years at our old Universities and great public schools, in the erection of laboratories, and in other ways for the promotion of science, because it has been for the purposes of instruction, and not of original research. No amount of ordinary instruction in science will remedy the evils caused by want of original inquiry, because such instruction does not produce new knowledge, but only disseminates that already possessed.

Many persons in this country think that all scientific men are investigators, and that a portion of the funds of scientific institutions generally are expended upon investigation, but such is rarely the case. Many also consider that those scientific men who are applying new knowledge are discovering new truths. And nearly all persons look upon inventors as the only really practical scientific men, and upon discoverers as unpractical enthusiasts who spend their lives in pursuit of vague theories. But whilst the inventor is a great and useful agent of civilization, there is one behind him who is greater than he, viz., the man who provides him with the new knowledge upon which all his inventions must be based.

The general aspect in which scientific research is viewed by many persons in this country, is that of a refined intellectual pursuit, which may be encouraged and honoured for the purpose of maintaining the tone of society. The question, however, is not whether this nation shall encourage research as a refined intellectual occupation, but whether it will contribute towards its own welfare by aiding scientific discovery.

Many persons also look upon scientific research as a hobby or as unpractical, and upon discoverers as mere accumulators of knowledge, but this is simply in consequence of their ignorance of the subject; if discoveries were commercial commodities, the practical character of research would be within their comprehension. A man who discovers knowledge for the use of invention is quite as practical a person as he who converts that knowledge into inventions fit for practical uses. The men who thus lead practical men must be practical themselves. Scientific discoverers may be considered the most practical men in existence, because their labours give rise to greater and more numerous practical results than those of any other persons. The discovery of a single substance, such as oil-of-vitriol, or washing-soda, has led to the formation of many valuable inventions, patented or otherwise, and to the establishment of thousands of manufactories. It is well known also that scientific discoverers are ardent lovers of truth, and are therefore very willing to communicate their knowledge for the good of mankind, and that manufacturers, men of business, and others, not unfrequently obtain from them and from their published researches, information of great value to themselves without even expecting to pay for it; forgetting that a scientific man may communicate in a passing remark, information which cost him years of labour to obtain.

Some persons also think that science is changeable and uncertain – that the discoveries of one generation are disproved by those of another, because they occasionally see scientific theories altered and superseded. But the real truth of the case is that the changes in the aspect of science which we continually witness do not often result from *alterations* in our stock of positive knowledge, but from *additions* made to it. Demonstrable truth is imperishable. It is true that many theories have been invented and entertained for a while in the minds of scientific men, and have then passed away, but we must remember that these are only the scaffolding of science, and no part of its real fabric. They consist of ideas which, whilst they assist us in understanding science, and in making discoveries, form no real part of our positive knowledge.

Other persons seem to think that the laws of matter are different in the laboratory from what they are in the workshop; that the principles which regulate a scientific experiment are different from those which govern a large manufacturing process; but this is a wrong idea. The laws of matter are universal, substances have nearly the same properties in all places and in the hands of all men; water boils at the same temperature whether in the retort of a chemist, the saucepan of a kitchenmaid, or the pan of a soap-boiler; iron wire is as readily deprived of its rust in a chemist's acid bottle as in a wire-drawer's pickling tub; a piece of phosphorus will as readily ignite in the hands of a chemist as in those of a match maker; a galvanic battery yields the same quantity of electricity whether it be in the hands of an experimentalist or in those of a working electro-plater.

It is true that many things which have appeared very promising in theory or in experiment, have failed altogether in practice, but why is this? it is not that the principles of nature operated in the one case and did not operate in the other, but that we have imperfectly understood them, that from some unforeseen circumstances we have been unable to apply them; or that we have indolently abandoned them without sufficient or proper trial. In many cases we are unable to obtain the same conditions of success upon the large scale that we have upon the small one. In other cases a process fails because of its too great expense; many attempts have been made to supersede steam as a motive power by means of electro-magnetism, and engines driven by that force have been constructed of five or ten horse-power, but the cost of driving them has been found to be at least ten times the amount of that of the steam-engine of equal strength. And in other cases we fail because we attempt *at once* to carry out upon a large scale that which has only been the subject of limited experiment, instead of enlarging the process by small degrees, and adapting the apparatus, the materials and the treatment, to the size of the operation.

That also which appears very simple in the hands of an experimentalist, almost invariably becomes much more complex when carried into practice in a manufactory, simply because there is then a greater number of conditions to be fulfilled. Electro-plating a piece of steel with silver is to a chemist a very simple matter, because it is of no importance to him whether the silver adheres firmly, is of good colour, or is deposited at a certain cost; but with a *manufacturer* unless *all* these conditions are fulfilled, the process is a failure. These matters, however, belong to invention and not to original discovery.

We should not condemn theoretical science because we are not able, even with fair and persevering trial, to apply it to any useful purpose, but wait patiently until circumstances ripen for its application. Many inventions which are inapplicable in one state of knowledge become applicable by the progress of scientific research. The idea of an electric telegraph, attempted by Mr. Ronalds, in the year 1816, with the aid of frictional electricity, had to wait the development of the galvanic battery and the discovery of electro-magnetism before it could be successfully applied.

Many manufacturers seem to think that because some of their operations are completely routine, and have been handed down to them by their predecessors in nearly their present state, they are not at all indebted to science; but there is no manufacture, especially among metals, which has not in some degree been aided by scientific discovery.

In addition to the great benefits accruing from original research to all classes of society, our Governments have also derived immense advantages from the same source. The revenues have been greatly increased by the universal advantages conferred upon all kinds of industry and commerce by scientific knowledge. The additional taxes upon increased incomes from agriculture, arts, manufactures, mines; increased value of land and rents; investments in railway, telegraph, steam-ship and other companies, have been extremely great. From the sale of patents alone, a surplus sum of nearly six hundred thousand pounds has already accumulated. Our Governments are also indebted to original research for the use of percussion-powder, gun-cotton, improvements in cannon, projectiles, rifles, armour-plated ships, the ocean telegraph, field telegraph, the telephone, rapid postal communication, the speedy transport of troops and war-material, and a multitude of other advantages. The value of science to Governments in the prevention of war by means of more ready correspondence through telegraph is incalculable. Mr. Sumner, of America, at the period when the Atlantic telegraph was first employed, stated that the use of that telegraph averted a probable rupture between Great Britain and America. There was a period when we did not possess such evidence of the great value of science; but that time has now passed away, and our governing men have had abundant proof of the national importance of scientific discovery, and of the essential dependence of the welfare of this country upon scientific research.

Whilst vast sums of money are spent upon the applications of science in military and naval affairs, research itself is neglected; the superstructure is attended to, but the foundations are left to decay. A very small proportion of the money which is expended upon military affairs would, if devoted to research, save a great deal of expense in warfare: —

"Were half the power, that fills the world with terror, —
Were half the wealth, bestowed on camps and courts,
Given to redeem the human mind from error,
There were no need of arsenals nor forts." – Longfellow.

Our Government has as yet made but little payment for the labour of pure research in experimental physics or chemistry; it has, however, given four thousand pounds a year for five years to be distributed by the Royal Society among scientific investigators, partly as personal payment. Income tax is deducted from these grants.

Want of recognition of the value of science has been so general in this country, that it is quite pleasing to quote a somewhat different case from the *Illustrated London News*, January 4th, 1873, viz., that of the late Archibald Smith, L.L.D., F.R.S. That gentleman was an investigator in pure mathematical science, and devoted the latter part of his life to the *application* of mathematics in the computation, reduction, and discussion of the deviation of the mariners' compass in wooden and in iron ships, and made practical deductions therefrom in the construction of those vessels. He published those practical applications of his scientific knowledge in the form of an Admiralty Manual, which was afterwards reprinted in various languages. Her Majesty's Government subsequently "requested his acceptance of a gift of two thousand pounds, not as a reward, but as a mark of appreciation of the value of his researches, and of the influence they were exercising on the maritime interests of England and the world at large." The kind of labour rewarded in this case was not scientific discovery, but the practical application of previously existing scientific knowledge.

The case of the late Dr. Stenhouse, F.R.S., is one of rather an opposite kind. That gentleman devoted his life throughout to pure investigations in organic chemistry, and published several of his researches in the Philosophical Transactions of the Royal Society.[9] His discoveries are very numerous, and although not much applied to practical uses by himself, the result of his researches on Lichens, and the yellow gum of Botany Bay, have been applied extensively by other persons in the manufacture of "French purple" and picric acid, and will doubtless continue to be applied to valuable uses. He held the Government appointment of Assayer to the Royal Mint, London, an office for several years unprofitable to him, but of increasing remunerative value, and which would have been subsequently worth £1,200 a year; but after the decease of his colleague, Dr. Miller, in 1870, that office, which was then worth to him about £600 a year, was abolished by the Chancellor of the Exchequer, and he lost the appointment, receiving, however, £500 as compensation. An application was therefore made to the Government, and a partial recompense to him was obtained, by Her Majesty granting him one hundred pounds a year "for eminence in chemical attainments, and on account of loss by suppression of office in the Mint." The only difference in these two instances, was, that in the second there was a very much greater amount of pure research and discovery, and a much smaller degree of applied knowledge.

[9] See "Royal Society Catalogue of Scientific Papers," vol. 5, pp. 719 and 890; and vol. 8, p. 1,010.

Конец ознакомительного фрагмента.