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LECTURES

ON

POPULAR AND SCIENTIFIC SUBJECTS

BY THE

EARL OF CAITHNESS, F.R.S.

DELIVERED AT VARIOUS TIMES AND PLACES.

Second Enlarged Edition.

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CONTENTS.

LECTURES ON POPULAR AND SCIENTIFIC SUBJECTS.

COAL AND COAL-MINES.

There are few subjects of more importance, and few less known or thought about, than our coal-mines. Coal is one of our greatest blessings, and certainly one originating cause of England's greatness and wealth. It has given us a power over other nations, and vast sums of money are yearly brought to our country from abroad in exchange for the coal we send. Nearly £17,000,000 is the representative value of the coal raised every year at the pit's mouth, and £20,000,000 represent its mean value at the various places of consumption. The capital invested in our coal-mining trade, apart from the value of the mines themselves, exceeds £20,000,000 sterling, and the amount of coal annually extracted from the earth is over 70,000,000 of tons. Taking the calculation of a working miner—J. Ellwood, Moss Pit, near Whitehaven—we may state, that if 68,000,000 tons were excavated from a mining gallery 6 feet high and 12 feet wide, that gallery would be not less than 5128 miles, 1090 yards, in length; or, if this amount of coal were erected in a pyramid, its square base would extend over 40 acres, and the height would be 3356 feet.

There are grounds for believing that the produce of the various coal-fields of the world does not at present much exceed 100,000,000 of tons annually, and therefore our own country contributes more than three-fifths of the total amount. If we divide the coal-yielding counties of Britain into four classes, so as to make nearly equal amounts of produce, we find that Durham and Northumberland yield rather more every year than seven other counties, including Yorkshire. Derbyshire, again, produces more than eight other counties, and nearly as much as the whole of North and South Wales, Scotland, and Ireland—the yield of the latter being about 17,000,000 of tons, and that of the two first-named about 16,000,000 of tons.

In 1773 there were only 13 collieries on the Tyne, and these had increased to upwards of 30 in 1800. The number of collieries in 1828 had increased to 41 on the Tyne, and 18 on the Wear, in all 59, producing 5,887,552 tons of coal. The out-put of coal in Northumberland and Durham in 1854 was no less than 15,420,615 tons, and now in these two counties there are 283 collieries. Mining began on the Tyne and continued on the Wear, where the industry has been largely developed. There are in all about 57 different seams in the Great Northern coal-field, varying in thickness from 1 inch to 5 feet 5 inches and 6 feet, and these seams comprise an aggregate of nearly 76 feet of coal. Taking the area of this field to be 750 square miles—a most probable estimate—we may classify the contents as household coal, steam coal, or those employed in steam-engine boilers, and coking coal, employed for making coke and gas. Of household coal there is only 96 square miles out of the total 750, all the remainder being steam or coking and gas coal. The greater part even of this 96 square miles has been worked out on the Tyne, and the supply is rapidly decreasing also on the Wear, where the largest bulk of the household coal lies. The collieries of the Tees possess but six square miles out of the 96, as far as we at present know. Turning, however, to that part of the coal-field regarded as precarious, and consisting of first, second, and third-rate household coal, we have for future use 300 square miles. London was formerly supplied from the pits east of Tyne Bridge, where is the famous Wallsend Colliery, which gave the name to the best coal. That mine is now drowned out, and, like the great Roman Wall, at the termination of which it was sunk, and from which it derived its name, is now an antiquity. There is now no Wallsend coal, and the principal part of the present so-called coal comes from the Wear, but the seam which supplied that famous pit is continued into Durham, and that seam, or its equivalent, sends a million or two of tons every year into London. The supply, however, in this district is rapidly decreasing. Careful calculations have been made as to the probable duration of this coal, of which the following is a summary. The workable quantity of coal remaining in the ten principal seams of this coal-field is estimated at 1,876,848,756 Newcastle chaldrons (each 35 cwt.). Deducting losses and underground and surface waste, the total merchantable round or good-sized coal will be 1,251,232,507 Newcastle chaldrons. Proceeding on this estimate, formed by Mr. Grunwith in 1846, we may arrive at the probable duration of the supplies: taking the future annual average of coal raised from these seams to be 10,000,000 of tons—and this is under the present rate—the whole will be exhausted in 331 years. A still later estimate was made by Mr. T.G. Hall in 1854, and he reckoned the quantity of coal left for future use at 5,121,888,956 tons; dividing this by 14,000,000 of tons as the annual consumption, the result would be 365 years; and should the annual demand arrive at 20,000,000 of tons, the future supply of this famous coal-field would continue for 256 years. The total available coal (1871) in the British coal-fields, at depths not exceeding 4000 feet, and in seams not less than 1 foot thick, is 90,207,285,398 tons, and taking into account seams which may yet become available, lying under the Permian, New Red Sandstone, and other superincumbent strata, this estimate is increased to 146,480,000,000 of tons. This quantity, at the present annual rate of production throughout the country—namely, 123,500,000 tons—would last 1186 years. Other estimates of various kinds relative to our coal supply have been put forth: some have asserted that, owing to increasing population and increasing consumption in manufactures, it will be exhausted in 100 years, and between this extreme and that of 1186 years there are many other conjectures and estimates.

In the United States there are about 120,000 square miles underlaid by known workable coal-beds, besides what yet remains to be discovered; while on the cliffs of Nova Scotia the coal-seams can be seen one over the other for many hundred feet, and showing how the coal was originally formed. With this immense stock of fuel in the cellars of the earth, it seems evident that we need not trouble our minds or be anxious as to the duration of our coal supply. Besides, the conversion of vegetable matter into coal seems to be going on even now. In the United States there are peat-bogs of considerable extent, in which a substance exactly resembling cannel coal has been found; and in some of the Irish peat-beds, as also in the North of Scotland, a similar substance has been discovered, of a very inflammable nature, resembling coal.

Yes! what could have produced this singular-looking, black, inflammable rock? How many times was this question asked before Science could return an answer? This she can now do with confidence. Coal was once growing vegetable matter. On the surface of the shale, immediately above the coal, you will find innumerable impressions of leaves and branches, as perfect as artist ever drew. But how could this vegetable matter ever accumulate in such masses as to make beds of coal of such vast extent, some not less than 30 feet thick? It would take 10 or 12 feet of green vegetable matter to make 1 foot of solid coal. Let us transport ourselves to the carboniferous times, and see the condition of the earth, and this may assist us to answer the question. Stand on this rocky eminence and behold that sea of verdure, whose gigantic waves roll in the greenest of billows to the verge of the horizon—that is a carboniferous forest. Mark that steamy cloud floating over it, an indication of the great evaporation constantly proceeding. The scent of the morning air is like that of a greenhouse; and well it may be, for the land of the globe is a mighty hothouse—the crust of the earth is still thin, and its internal heat makes a tropical climate everywhere, unchecked by winter's cold, thus forcing plants to a most luxurious growth.

Descend, and let us wander through this forest and examine it more closely. What strange trees are here! No oaks, no elms, or ash, or chestnut—no trees that we ever saw before. It looks as if the plants of a boggy meadow had shot up in a single night to a height of 60 or 70 feet, and we were walking among the stalks—a gigantic meadow of ferns, reeds, grasses, and club-mosses. A million columns rise, so thick at the top that they make twilight at mid-day, and their trunks are so close together we can scarcely edge our way between them, whilst the ground is carpeted with trailing plants completely interwoven. What strange trees they are! Beneath us lies an accumulation of vegetable matter more than 200 feet in thickness—the result of the growth and decay of plants in this swamp for centuries. All things are here favourable for the growth of vegetation—the great heat of the ground causes water to rise rapidly in vapour, and this again descends in showers, supplying the plants with moisture continuously. The air contains a large proportion of carbonic acid gas, poison to animals but food to plants, which, by means of its aid, build up their woody structure. Winds at times level these gigantic plants, for their hold on the earth is feeble, and thus the mass goes on increasing.

We are now on the edge of a lake abounding with fish, whose bony scales glitter in the water as they pursue their prey. Lying along the shore are shells cast up by the waves, and there are also seen the tracks of some large animals. How like the impression of a man's hand some of these tracks are! The hind-feet are evidently much larger than the fore-feet. There is the frog-like animal which made them, and what a size! It must be six feet long, and its head looks like that of a crocodile, for its jaws are furnished with formidable rows of long, strong, sharp, conical teeth.

The continued growth and decomposition of the vegetation during long ages must have produced beds like the peat-deposits of America and Great Britain. In the Dismal Swamp of Virginia there is said to be a mass of vegetable matter 40 feet in thickness, and on the banks of the Shannon in Ireland is a peat-bog 3 miles broad and 50 feet deep. When conditions were so much more favourable for these deposits, beds 400 feet in thickness may easily have been produced. This accumulated mass of vegetable matter must be buried, however, before we can have a coal-bed. How was this accomplished? The very weight of it may have caused the crust of the earth to sink, forming a basin into which rivers, sweeping down from the surrounding higher country, and carrying down mud in their waters, the weight of which, deposited upon the vegetable matter, pressed and squeezed it into half its original compass. Sand carried down subsequently in a similar manner, and deposited upon the mud, pressed it into shale, and the vegetable matter, still more reduced in volume by this additional pressure, is prepared for its final conversion into shale. In time the basin becomes shallow from the decomposition of sediment on its bottom, and then we have another marsh with its myriad plants; another accumulation of vegetable matter takes place, which by similar processes is also buried. Where thirty or forty seams of coal have been found one below another, we have evidence of land and water thus changing places many times.

When vegetable matter is excluded from air and under great pressure, it decomposes slowly, parting with carbonic acid gas; and is first changed into lignite or brown coal, and then into bituminous coal, or the soft coal that burns with smoke and flame. I have been in a coal-mine where the carbonic acid gas, pouring from a crevice in the coal, put out a lighted candle. The high temperature to which the coal has been subjected when buried at great depths has also probably assisted in producing this change; and where that temperature has been very high, the coal by the influence of the heat having parted with its inflammable gases, we have the hard or anthracite coal, which burns with little or no flame and without smoke. It is indeed coal made into coke under tremendous pressure, and this is the kind of coal which Americans use exclusively in their dwelling-houses and monster hotels.

It was at first supposed that the plants of the carboniferous times were bamboos, palms, and gigantic cactuses, such as are now found in tropical regions, but a more careful examination of them shows that, with the exception of the tree-fern now found in the tropics, they differ from all existing trees. A large proportion of the plants of the coal-measures were ferns, some authorities say one-half. From their great abundance we may infer the great heat and moisture of the atmosphere at the time when they grew, as similar ferns at the present day are only found in the greatest abundance on small tropical islands where the temperature is high. Coal often contains impressions of fern leaves and palm-like ferns—no less than 934 kinds are drawn and described by geologists. Many animals and insects are found in the coal, such as large toad-like reptiles with beautiful teeth, small lizards, water lizards, great fish with tremendous jaws, many insects of the grasshopper tribe, but none of these are of the same species as those found now living on this globe.

Wood, peat, brown coal, jet, and true coal, are chemically alike, differing only in their amount of oxygen, due to the difference of compression to which they were subjected. The sun gave his heat and light to the forests now turned into coal, and when we burn it ages afterwards, we revive some of the heat and light so long untouched. Stephenson once remarked to Sir Robert Peel, as they stood watching a passing train: "There goes *the sunshine of former ages*!"

COST OF WORKING.

Having thus stated shortly the origin and extent of the coal of this country, more particularly that of the northern coal-fields of Northumberland and Durham, I think it may be interesting to say something of the cost at which this valuable article is obtained, as I am sure few are at all aware of the vast sums of money that have to be expended before we can sit down by our comfortable firesides, with a cold winter night outside, and read our book, or have our family gathered round us; and few know the danger and hardship of the bold worker who risks his life to procure the coal. The first step is to find out if there is coal. This done, the next is to get at it, or, as it is termed, to *win* the coal. The process is to sink a shaft, and this is alike dangerous, uncertain, and very costly. The first attempt to sink a pit at Haswell in Durham was abandoned after an outlay of £60,000. The sinkers had to pass through sand, under the magnesian limestone, where vast quantities of water lay stored, and though engines were erected that pumped out 26,700 tons of water per day, yet the flood remained the conqueror. This amount seems incredible, but such is the fact. At another colliery near Gateshead (Goose Colliery), 1000 gallons a minute, or 6000 tons of water per day, were pumped out, and only 300 tons of coal were brought up in the same time, and thus the water raised exceeded the coal twenty times. The most astonishing undertaking in mining was the Dalton le Dale Pit, nine miles from Durham. On the 1st June 1840 they pumped out 3285 gallons a minute. Engines were erected which raised 93,000 gallons a minute from a depth of 90 fathoms or 540 feet, and this was done night and day. The amount expended to reach the coal in this pit was £300,000. Mr. Hall estimates the capital invested in the coal trade of the counties of Durham and Northumberland, including private railways, waggons, and docks for loading ships, at £13,000,000 sterling.

The great difficulty in working coal, should these upper seams fail, is not only the increase of cost in sinking further down, but the increased heat to be worked in. At 2000 feet the mine will increase in heat 28°, at 4000, 57°; to this must be added the constant temperature of 50° 5', so that at 2000 feet it would be 78° 5', and at 4000, 107° 5' Fahr. By actual trial on July 17, 1857, in Duckingfield Pit, the temperature at 2249 feet was 75° 5'. From this it may be conceived in what great heat the men have to work, and the work is very hard. One may fancy from this what can be endured, but it would be next to impossible to work in a greater temperature. I can speak upon this from actual experience, as when down the Lady Londonderry Pit the temperature was 85°, and here the men worked naked. Another great source of expense and anxiety lies in keeping up the roof, as, from the excessive pressure, the roof and floor are always inclined to come together, and props must therefore be used, and these in some pits cost as much as £1500 a year. To digress for a moment, an amusing story is told of Grimaldi, the celebrated clown, when paying a visit to a coal-pit. Having gone some way through the mine, a sudden noise, arising from the falling of coal from the roof, caused him to ask the reason of the noise. "Hallo!" exclaimed Grimaldi, greatly terrified, "what's that?" "Hech!" said his guide, "it's only a wee bit of coal fallen down—we have that three or four times a day." "Then I'll thank you to ring for my basket, for I'll stop no longer among the wee bits of falling coal." This "wee bit" was about three tons' weight. A large proportion of the sad accidents in coal-mines is caused by these falls of the roof, which give no warning, but suddenly come down and crush to death those who happen to be near.

MODE OF WORKING.

The cost of working having thus been given, I wish now to lay before you an explanation of the method of working and bringing the coal to the surface. It may not be uninteresting to mention how many men are employed in this work, as the number is very large. Coal was not formerly excavated by machinery, but it is so now, and therefore hands must be had. The number of men employed in the mines of county Durham in 1854 was 28,000; of these, 13,500 were hewers, winning several thousand tons of coal daily. Of the remainder, 3500 were safety-staff men, having, besides, 1400 boys belonging to their staff; 2000 were off-hand men, for bargain work or other duties; 7600 lads and boys, working under the various designations of "putters," or pushers of coal-tubs, underground "drivers," "marrows," "half-marrows," and "foals," these latter terms being local, and significant of age and labour. For Northumberland must be added 10,536 persons, and Cumberland 3579, making a total for these three counties of upwards of 42,000 persons labouring in and round our northern collieries. The average that each hewer will raise per day is from two to three tons in thin, and three to four tons in thick seams. The largest quantity raised by any hewer on an average of the colliers of England is about six tons a day of eight hours. The mode of working is very laborious, as the majority of seams of coal being very thin—that is to say, not more than two feet thick—the worker of necessity is obliged to work in a constrained position, often lying on his side; and you can fancy the labour of using a pick in such a position. To get an idea of the position, just place yourself under a table, and then try to use a pick, and it will give you a pretty clear idea of the comfortable way in which a great part of our coal is got, and this also at a temperature of 86° in bad air. The object, of course, of the worker is to take nothing but coal, as all labour is lost that is spent in taking any other material away. The man after a time gets twisted in his form, from being constantly in this constrained position, and, in fact, to sit upright like other men is at last painful. Then an amount of danger is always before him, even in the best regulated and ventilated pits. This danger proceeds from fire-damp, as one unlucky stroke of the pick may bring forth a stream of carbureted hydrogen gas, inexplosive of itself, but if mixed with eight times its bulk of air, more dangerous than gunpowder, and which, if by chance it comes in contact with the flame of a candle, is sure to explode, and certain death is the result—not always from the explosion itself, but from the after-damp or carbonic acid gas which follows it.

Upwards of 1500 lives are yearly lost from these causes, and not less than 10,000 accidents in the same period show the constant danger that the miner is exposed to. It would appear that England has more deaths from mining accidents than foreign countries, as Mr. Mackworth's table will show:—

Prussia	1.89 per 1000	
Belgium	2.8	"
England	4.5	"
Staffordshire	7.3	"

This statement shows that more care is wanted in this last-named county especially, as I find that the yield of coal in Belgium is half as much as in England. Long working in the dark, if one may so speak, is a cause of serious detriment to the sight, and the worker also suffers much from constantly inhaling the small black dust, which in course of time affects the lungs, causing what is known as "miner's asthma." Without going further into the unhealthy nature of the miner's work, it may be interesting to mention something of the actual process, and having myself been an eye-witness of it, I will explain it as shortly as I can. The workers having arrived at the pit-mouth at their proper hours—for the pit is worked by shifts, and consequently is generally worked day and night—the first operation is for each to procure his lamp from the lamp-keeper, receiving it lighted and locked; this is found to be necessary, as from the small light given by the Davy-lamp the men are often tempted to open them, and some are even, so foolhardy as to carry their lamp on their cap and a candle in the hand, and hence a terrible explosion may take place. A few words on the Davy-lamp, which came into use about sixty years ago, may not be out of place here. This safety-lamp of the miner not only shows the presence of gas, but prevents its explosion. It is constructed of gauze made of iron-wire one-fortieth to one-sixtieth of an inch in diameter, having 784 openings to the inch, and the cooling effect of the current passing through the lamp prevents the gas taking fire. If we pour turpentine over a lighted safety-lamp, it will show black smoke, but no flame. Provided with his lamp, the miner takes his place with others in the tub, which conveys him with great rapidity to the bottom of the shaft. Here landed, he takes his way to the workings, some of these, in large pits, being two miles from the bottom of the shaft. To a novice this is not easy, as you have to walk in a crouching manner most part of the way. Once there, he begins in earnest, and drives at his pick for eight hours, the monotony only relieved by his gathering the products into small railway waggons or tubs to be removed. This is done mostly by boys, but in the larger mines by ponies of the Shetland and other small breeds. The tubs are taken to a part of the mine where, if one may so speak, the main line is reached, and then formed into trains, and taken to the shaft by means of an endless rope worked by an engine in the pit. In accomplishing all this work, great care has to be taken that the current of air is not changed or stopped. This is effected by means of doors placed in various parts of the mine, so as to stop the current and drive it in the required direction. These doors are kept by boys, whose duty it is to open and close them for the passage of the coal tubs. Those boys are often allowed no light, and sit in a hole cut in the side of the road near to the doors. Upon their carefulness the safety of the mine in a great measure depends, as if they neglect to shut the door the current of air is changed. I have been told that these boys are subject to accidents no less than the workers, for, sitting in the dark, and often alone for hours, they are very apt to go to sleep. To ensure being awoke at the proper time, they frequently lie down on the line of rails under the rope, so that when the rope is started it may awake them by its motion, but at times so sound is their sleep, that it has failed to rouse them in time, and a train of coal waggons has passed over them, causing in most cases death.

The coal having been brought to the pit-mouth, it remains to be shown what becomes of this most valuable mineral, the consumption of which is now so large in all parts of the globe. The next person employed in the trade is the sailor, to convey it to the market, and the collier vessels are a valuable navy to the country, proving quite a nursery of seamen for our royal marine service. Newcastle, Sunderland, West Hartlepool, and a large number of other ports along our coast, have an immense amount of shipping employed exclusively in the coal trade—no less than 5359 vessels carrying coal having entered the port of London alone in 1873, and the average annual quantity of coal exported abroad during the three years ending 1872 was 12,000,000 tons.

I will not now detain you longer on the subject of the extent and working of coal, lest I should tire your patience; but before concluding I should wish to give some account of the uses to which this most valuable product is applied. The main use of coal, as we all know, is to produce heat, without which many a paterfamilias would grumble when the dinner-hour came and he had nothing hot to eat. It not only, however, supplies heat, but the beauty of the processes for lighting up our houses is now mainly derived from coal. The immense consumption of coal, among other things, is in the production of the vapour of water—steam, by which our thousands of engines on sea and land are made to perform their various appointed tasks. This production, formed of decayed vegetable matter, which in ages past nourished on the surface of the earth, as I have already shown, is again brought forth for our use, and is a testimony of the goodness and kindness of God in providing for our wants. By its heat some 10,000 locomotive engines are propelled, and many hundreds of iron furnaces are kept in work, besides those for other purposes. It moves the machinery of at least 3000 factories, 2500 steam vessels, besides numerous smaller craft, and I cannot tell how many forges and fires. It aids in producing delicacies out of season in our hothouses. It lights our houses and streets with gas, the cheapest and best of all lights—London alone in this way spending about £50,000 a year. It gives us oil and tar to lubricate machinery and preserve timber and iron; and last, not least, by the aid of chemistry it is made to produce many beautiful dyes, such as magenta and mauve, and also, in the same way, gives perfumes resembling cloves, almonds, and spices.

The annual consumption of coal in Great Britain is reckoned to be not less than 80,000,000 tons. The amount raised in 1873 amounted to 127,000,000 tons, and of this was imported into London alone 7,883,138 tons—4,000,000 tons, or 15 per cent. of the total out-put of the country, being sent from Durham alone. The cost of the Wallsend coal on board the ship may be stated at 10s. 6d. per ton; to this must be added the charge at coal-market of 2s. 8d., freight say 5s. 9d., profit 7s. 6d., so that a ton of coal of this kind will cost in your cellar in London the sum of £1, 6s. 5d.

I think it is now time to conclude this most interesting subject, for though I have by no means exhausted it, yet I fear I have said as much as a lecture will warrant. The subject shows us how mindful a kind Providence has been of man, and to this nation in particular, for to our coal we in a measure owe much of our greatness. So while we admire the geology of our globe, let us not forget who made it and all that it contains, and who, when He had finished the work, pronounced it all very good. Let us so strive to live, that though we may be called away suddenly, as 199 of our fellow-creatures were called by what is termed a mining accident, we may be ready to meet Him who not only made us, but made the coal, and who, when man, at first made perfect, fell away, was pleased to send a Saviour to redeem us and bring us to that light which fadeth not away.

SCIENCE APPLIED TO ART.

A resumé of science and art requires to set forth what they have already done and what they are now doing—to trace them down to our own time, and contrast their early stages with their present development. Giving to art and science all that is their due, it must be evident to every one that they are primarily not of human origin, but owe their existence and progress to those inherent faculties of man which have been bestowed upon him by an Almighty Being—faculties given not only to fathom the works of creation, and adapt them for man's use and benefit, but also that they might show forth the praise and honour of their Creator, as "the heavens declare the glory of God, and the firmament showeth His handiwork." To set forth science and art before an Institution like that here met together, behoves one to enter upon the subject in a way which will not only interest but also instruct. But this is only an opening address, and the lecturers who will follow me in due course will bring before you the special interests of those special subjects on which they are to treat. These cannot fail to interest as well as instruct those who attend, their object being profit to the mind, and hence not only the furtherance of mental culture, but increasing capabilities for material prosperity.

To address a meeting in Glasgow gives one a feeling of pleasure; but, before going further, I trust that when I have finished you may not be able to say of me, as the two Highlanders did after leaving church—"Eh, man! wasna that a grand discoorse?—it jumbled the head and confused the understanding!" This city has brought forth one of the greatest of men—though, like many others, he had to fight an uphill battle in his early career—that man was James Watt. But what a career was his! and what a benefit to all now living has proved the result of his perseverance, for to his genius are we mainly indebted for the manifold applications of the wondrous power of *Steam*! That word is enough; and the engines it now propels are a powerful testimony to the talent of the great man who brought this mighty power to bear on the vast machinery, not only of this great country, but of the whole world. Contrast, for one thing, the travelling facilities of Watt's early days with those we now possess through his persevering industry. Fourteen days was then the usual time for a journey from Glasgow to London, while at present it can be performed in a less number of hours.

Railways! what have they not done! We see towns spring up in a few years where only a few cottages formerly stood, and wild glens transformed into fruitful valleys, by means of railways in their neighbourhood developing traffic and trade, and creating employment by placing them in communication with larger towns, and thus opening up new sources of material prosperity. Look at the magnitude of our railways. With respect to locomotives alone, in 1866 there were 8125 of these, and the work performed by them was the haulage of 6,000,000 trains a distance of 143,000,000 miles. As each engine possesses a draught-power equal to 450 horses, these 8125 locomotives consequently did the work of more than 3,500,000 horses, and as the average durability of a locomotive is computed to be about fifteen years, each will have in that time traversed nearly 300,000 miles! Then, again, there have to be replaced about 500 worn-out locomotives every year, at a cost for each of about £2500 to £3000, entailing an annual expenditure of nearly £1,500,000 sterling. All this money circulates for the country's benefit, keeping our iron, copper, and coal mines, our furnaces and our workshops, all at work, and our people well and usefully employed, and thus proving one of the greatest advantages of applied science and art to this country and the world at large. If it had not been for steam, this valuable Institution might not have been in existence, having for its chief objects the promotion of the growth and increasing the usefulness of the applied sciences.

We have now one of the greatest triumphs of engineering art in the Mont Cenis Railway, and this, though worked out under great difficulties, has proved a perfect success. Still more recently we have had brought under our notice the bold scheme of connecting Britain and France by a tunnel under the English Channel—a project which, but a few years ago, any one would have been thought mad to propose; but science has proved that it can be carried out; and it is only a few days since a large meeting was held in Liverpool with a view of tunnelling under the Mersey, and thus connecting Liverpool and Birkenhead. Nor do these schemes seem at all visionary when we learn that our go-ahead Transatlantic cousins have a project before the Legislature of New Jersey for laying wooden tubes underground, through which the mails and small parcels will be forwarded at the rate of 150 miles an hour! Through a similar tube, 6 feet in diameter, laid under the East and Hudson Rivers, passengers are to be transported from Brooklyn to Jersey city. A like scheme is in course of construction under the Thames.[A] Another American engineering triumph will be the railway suspension bridge proposed to be built across the Hudson River at Peekskill, in the hilly district known to New Yorkers as the Highlands, which is to have a clear span of 1600 feet at a height of 155 feet above high water.

Another grand and comparatively recent application of steam is in its adaptation to agriculture. Fields are now turned up by the steam-plough—an invention as yet in its infancy—in a manner that could never be done by mere hand-labour. Steam-culture has already penetrated as far north as John-o'-Groats, where I have one of the ploughs of Mr. Howard of Bedford, and but for its assistance I could not have taken in the land I have now worked up. So great is the demand for steam-cultivating apparatus, not only in Britain, but throughout the German plains and the flat alluvial soils of Egypt, that the makers have now more orders than they can readily supply.

In all our manufactories steam proves itself the motive power, and there is hardly a large work without it. This city can show its weaving, spinning, bleaching, and dyeing works—all which have tended to raise Glasgow from the small town of Watt's time to the proud position it now holds of being the first commercial city of Scotland. In this city, second only to Manchester in the production of cotton goods, it cannot fail to be interesting to state, that in the first nine months of the present year there has been exported 2,188,591,288 yards of cotton piece-goods manufactured in this country—a larger quantity by nearly 150,000,000 yards than the corresponding period of 1867, the year of the largest export of cotton manufactures ever known until then. Of course Glasgow has had its share in this great branch of export trade, rendering it large, wealthy, and populous—results which have mainly followed from the application of science to art.

Last, not least, see what steam has enabled us to do in regard to the food for the mind, both in printing it and afterwards in its distribution. Look, for instance, to Printing House Square—to the "Times" newspaper. In the short space of one hour 20,000 copies are thrown off the printing-machine, and, thanks to the express train, the same day the paper can be read in Glasgow. Still further in this direction, the value of steam is also shown by its having enabled us to produce cheap literature, so strikingly instanced in the world-famed works of Sir Walter Scott, which we are now enabled to purchase at the small sum of sixpence for each volume—a result which well shows the application of science to art.

Let us now observe what a varied number of mechanical and agricultural appliances are required to furnish us with this cheap literature. There is agriculture, in the growth of the fibre that produces the material of which the printing paper is made; then the flax-mill is brought into play to produce the yarn to be woven; then weaving to produce the cloth; after this, dyeing. Then the fine material is used for various purposes too numerous to mention; and after it has performed its own proper work, and is cast away as rags, no more to be thought of by its owner, it is gathered up as a most precious substance by the papermaker, who shows us the true value of the cast-off rags. Subjected to the beautiful and costly machinery of the paper-mill, the rags turn out an article of so much value that without it the world would almost come to a stand-still. Yet further, we have next the miner, who by his labour brings to the surface of the earth the metal required to produce the type for printing; after this the printing-press; and next the chemist, who by certain chemical combinations gives us the ink that is to spread knowledge to the world, by making clear to the eye the thoughts of authors who have applied their minds for the instruction and amusement of their fellow-men. But we do not end here; consider also that each and all, the farmer, the spinner, the weaver, the chemist, the miner, the printer, and the author, must respectively have a profit out of their various branches of industry, and does it not strike one forcibly what a boon to the world is this all-important application of science to art—putting within the reach of the poor man and the working man the means of cultivating his mind, and so, by giving him matters of deep interest to think over, keeping him from idleness and perhaps sin (for idleness is the root of most evil), and making him a happy family-man instead of a public-house frequenter.

Many were strongly opposed to the introduction of steam, and would rather have seen it put down, and the old coach and printing-press, loom, spinning-wheel, and flail kept in use, fearing that machinery would limit employment; and a hard fight it has been to carry forward all that has hitherto been done. But what has proved to be the result? Thousands are now employed where formerly a few people sufficed, and we are all benefited in having better and cheaper goods, books, provisions, and all things needful. There is therefore the satisfaction of knowing that, by the thousand and one applications of steam, the physical, mental, and even moral condition of the people has been greatly ameliorated; in this way again proving a triumph for the application of science to art.

Glasgow is not only famous for its multifarious applications of water in its finely divided gaseous form of steam, but it has made admirable use of that element in its more familiar and fluid form, as shown in the gigantic undertaking of bringing a water-supply into this thriving and populous city. The peaceful waters of a Highland lake are suddenly turned from their quiet resting-place, where they have remained in peace for generations, the admiration of all beholders, and made to take an active part in contributing to the health, wealth, and comfort of Glasgow. The beautiful Loch Katrine has been brought into the city, furnishing a stream of pure water to minister to the wants of all classes of the people—an undertaking which a few years ago would have been pronounced impossible; but here again science and art have prevailed, and brought about this all-important object and greatly desired and inestimable boon. The great capital of England itself cannot boast of such an advantage, and must still be content to drink water contaminated with impurities. Does not this speak volumes for the wealth and energy of Glasgow? What so conducive to health and cleanliness (and cleanliness is akin to godliness) as a pure and perfect supply of water such as you now possess; and you have great reason to be grateful for this beneficent application of science and art. With a worldwide celebrity for your waterworks, you have cause also to be proud of your chemical works, and that famous chimney of St. Rollox, one of the loftiest structures in the world. There are few cities more highly favoured than this. Would not Captain Shaw be glad if, in London, he had the head or command of water such as you have from Loch Katrine to save the great metropolis from the destruction by fire that they are in daily dread of? In Glasgow we hardly want this—our grand Loch Katrine does it all.

Turn to your river, the beautiful Clyde, which eighty years ago could be forded at Erskine, while Port Glasgow was as far as ships could then come up—a striking contrast to what is now to be seen at the Broomielaw, where the largest steamers and ships drawing thirty feet of water are moored in the very heart of the city, discharging produce from all parts of the world. What has done this but steam—the energy of man; steam cutting a channel by dredging to admit of ships passing so far up the river: and this has been to Glasgow a great source of wealth by the promotion of commerce. Art has been permitted to work out great things for your city, and I trust still greater things are in store. Take the trade now in full progress on the banks of the Clyde. The shipbuilding is fast leaving the Thames and finding its way here. It is a pleasure to hear people say: "There is a fine ship—she is Clyde-built."—"Who built her? Was it Napier, or Thomson, or Tod, or M'Gregor, or Randolph & Elder, or Caird, or Denny of Dumbarton, or Cunliff & Dunlop?" Pardon me if I have left out any name, for all are good builders. Then, again, it may be asked: "Who engined these ships?"—"Oh, Clyde engineers, or those who built them." I had the pleasure of being this year on board the Trinity yacht "Galatea," on a cruise when fourteen knots an hour were accomplished; and that yacht is a good specimen of what Clyde shipbuilders can turn out. She was built by Caird. I have also had the pleasure of a trip in the "Russia," one of the finest screw-vessels afloat, built by Thomson; and she has proved herself perhaps the fastest of sea-going steamers. Does not all this show what science applied to art has done?

Glasgow has also a College of the first order, one that is looked up to as sending men of high standing forth to the world. Watt worked under its roof as a poor mathematical instrument maker, and although enjoying little of its valuable instruction, he produced the steam-engine—a lesson as to what those ought to do towards promoting the application of science to art who have the full benefit of a scientific training such as your College affords.

Each day brings forth something new—the electric telegraph, for instance, by which our thoughts and desires are transmitted to all parts of the world, so to speak, in a moment of time. When we think that we are within an instant of America, it gives one a feeling of awe, for it shows to what an extent we have been permitted to carry the application of science to art. A small wire is carried across the great Atlantic, and immediate communication is the result. The achievements of science were shown to a great extent in the laying of this cable, and perhaps still more in its recovery after it had been broken. A small cable is lost at the bottom of the ocean, far from the land, and in water about two miles in depth—a ship goes out, discovers the spot, and then grappling irons are lowered. Science with its long arm, as it were, reaches down the almost unfathomable abyss, and with its powerful hand secures and brings to the surface of the ocean the fractured cable, which is again made to connect the Old and New Worlds—thus verifying almost the words of Shakespeare, when he speaks of calling "spirits from the vasty deep." After splicing the cable, the vessel proceeds with the work of paying it out, as it sails across the Atlantic; and once more science and art find a successful issue, for Europe and America are united.

What the combination of science and art has done is, however, not yet exhausted: witness the splendid specimens of artillery now produced by Sir Joseph Whitworth and Sir William Armstrong—weapons by which projectiles are thrown with an almost irresistible force. The beauty of their construction is a triumph to art, and their mathematical truth a triumph to science. One thing follows another, and no sooner have men of originality and observation perfected the means of destruction, when others press forward and furnish the means of defence. Our armour-clads, such as the "Warrior" and others which lately visited these waters, have thus been called into existence, and they are splendid specimens of what science applied to art can achieve.

The Menai Bridge is another instance of the power of man in applied science. A railway bridge is required to further communication, but Government demands that the navigation of the Strait shall not be impeded. The mind of a great man is called into action, and by applying scientific principles to engineering art, we have that wonder of the world, the great tubular bridge over the Menai Straits. This work required a mind of no ordinary nature, but such a one was found in the celebrated Robert Stephenson. I am proud to say I was privileged to have him as a friend, and I greatly lamented his death, not only as a friend, but as an irreparable loss to the world of science.

Another instance of science applied to art—and not the least important—is the adaptation of glass to form the lens which enables the flame of a lamp to be seen from a great distance. What this has done for the mariner is shown in our lighthouses, which enable him to know where he is by night as well as by day, for the lights are made to revolve, to be stationary, or to show various colours or flashes, which reveal to him their respective positions. The compass also, though ancient, is still an application of applied science, and by it the mariner is enabled to guide his ship safely over the ocean. A very beautiful instance of applied science to art is electrometallurgy, in which metals are deposited by means of the galvanic battery in any required form or shape, and this process of gilding and plating is executed with marvellous rapidity. All these various instances show what the mind of man has done, and is doing; but the applications of science to art are so endless, that even their simple enumeration could not be included in the limits of an opening address, for there are few things to which science cannot be applied. One of the most recent and beautiful is the art of photography, where, by means of applied chemistry, aided by the rays of the sun, there can be produced the most pleasing and lifelike representations. This new application of chemistry is a most interesting one, which shows that we do not stand still, and as long as arts and science are permitted to be practised by us we are not intended to stand still, but to exercise our minds to the utmost to unravel those mysteries of nature that are yet to be developed.

Chemistry, as a regular branch of natural science, is of comparatively recent origin, and can hardly be said to date earlier than the latter third of last century. The Greek philosophers had some vague yet profound ideas on this subject, but their acquaintance was limited to speculations *à priori*, founded on general and often inaccurate observations of natural occurrences. Yet their acuteness was such, that some of their speculations as to the constituent properties of matter coincide in a wonderful degree with those which now prevail among modern philosophers. It is not easy to define what chemistry is in a few words, but it may be described as the science which has for its object the investigation of all elementary bodies which exist in the universe, with the view of determining their composition and properties. It also seeks to detect the laws which regulate their mutual relations, and the proportions in which these elements will combine together to form the compounds which constitute the animal, vegetable, and mineral kingdoms, as well as the properties of these various compounds. The ancients admitted only four elements—earth, air, fire, and water. Chemists now far exceed this number, and seek to show what these elements are composed of by analysing them into the various gases, solids, and liquids.

Astronomy is the most ancient of all the sciences. The Chaldeans, the Egyptians, the Chinese, the Hindoos, Gauls, and Peruvians, each regarded themselves as the inventors of astronomy, an honour which Josephus deprives them of by ascribing it to the antediluvian patriarchs. From the few facts to be gleaned out of the vague accounts by ancient authors regarding the Chaldeans, it may be inferred that their boasted knowledge of this science was confined to observations of the simplest kind, unassisted by any instruments whatever. The Egyptians, again, though anciently considered the rivals of the Chaldeans in the cultivation of this science, have yet left behind them still fewer records of their labours, though it is so far certain that their astronomical knowledge was even greater than that of the Chaldeans. The Phoenicians seem to have excelled in the art of navigation, and would no doubt direct their course among the islands of the Mediterranean by the stars; but if they had any further speculative notions of astronomy, they were probably derived from the Chaldeans or Egyptians. In China, astronomy has been known from the remotest ages, and has always been considered as a science necessary and indispensable to the civil government of the Celestial Empire. On considering the accounts of Chinese astronomy, we find it consisted only in the practice of certain observations, which led to nothing more than the knowledge of a few isolated facts, and they are indebted to foreigners for any further improvements they have since adopted.

The Greeks seem to have made the most early advances in astronomy; for notwithstanding that the art of observation was still in its infancy, we are indebted to the labours and speculations of ancient Greek philosophers for raising astronomy to the dignity of a science. The complicated but ingenious hypotheses of the Greek Ptolemy prepared the way for the discovery of the elliptic form of the planetary orbits and other astronomical laws by the German Kepler, which again conducted our English Newton to the discovery of the law of gravitation. I am not, however, desirous of giving this meeting a lecture on astronomy—I shall leave that to Professor Grant. But it is singular that I should have come here on a day on which one of the now known observations and movements of the planets has taken place—the transit of Mercury. This was calculated to occur this day by the science of astronomy, and it is also known when it will again occur, namely, on the 6th of May 1878. I will end this subject by saying, that the discoveries in astronomy in the last and present centuries have been so many and interesting, that it would be quite impossible for me to enter here minutely upon them.

In conclusion,—What have science and art done for us? They have cultivated our minds—they have made us think, wonder, and admire, and I trust caused us to adore and reverence the Creator of this vast universe. They have taught us the knowledge and value of time, and have also shown the value of what man has been enabled to work out for his own benefit and that of the world at large.

The chemist deals with the various substances brought under his notice, thereby acquiring a knowledge of their properties, enabling him to produce results which are truly beneficial. This knowledge is power.

The painter makes the features of Nature his study, and by his brush delineates them on the canvas, and thus by knowledge of art he exhibits power.

The astronomer's science is one of vast magnitude and importance—the study of it embracing both science and art: science in the various intricate calculations he requires to make in connection with the heavenly bodies. By his researches we have discovered the form of the earth and other planets, their respective distances from each other, their revolutions, their eclipses and their orbits, and, more wonderful still, the precise time when the various movements of each occur. In art, the astronomer has originated and perfected the many powerful and beautiful instruments now required for taking observations, and these, when compared with the instruments in use in bypast times, are excellent evidences of modern progress in this direction. Our wonder is excited when we look at the instruments formerly in use; that so much was done through them, and the advance made by art in the perfection of those now adopted, show us again that knowledge is power.

The navigator, by a combination of astronomy and seamanship, is enabled to plough the great deep, and at all times by mathematical calculation to discover the exact position of his ship. What, however, would he be without the aid of art? The compass, the sextant, or quadrant, &c., are the means which enable him to attain these grand results, and to bring his ship to the desired haven. The use of these is knowledge, and this knowledge is power.

Alike with all other things which science and art have called into use, knowledge is power, and this power was given by the Almighty, as I said at the beginning of this lecture, to enable man to fathom the works of creation. Let us then so live that we may ever admire the results of the labours of science and of art, and at the same time ever remember Him who has given us the power to discover and use them for our benefit,—thanking God, who first made all things and pronounced them very good, for His great mercy toward us.

FOOTNOTES:

[A] Now carried out.

A PENNY'S WORTH;

OR,

"TAKE CARE OF THE PENCE, AND THE POUNDS WILL TAKE CARE OF THEMSELVES."

A penny seems a small sum to talk about, and with many, I am sorry to say, is looked upon as so insignificant as to be considered almost worthless; but I hope, before I have done, to show you something of the great value of even a penny, and of the effects and products we have been enabled to produce and dispose of with a reasonable profit at the cost of one penny. A much smaller sum than this was looked upon and regarded as of inestimable value by our blessed Saviour, when He saw the rich men and the widow casting their offerings into the treasury, for He said: "All these have of their abundance cast in unto the offerings of God: but she of her penury hath cast in all the living that she had."

Now what did this widow cast in? Two mites, which make one farthing. Though this took place more than eighteen hundred years ago, it shows to us even now the great value of small things when given with the heart and used in the right way.

Money is a most desirable thing, and without it the business of the world would come to a stand-still, but how to spend it aright is a matter of grave thought, for it may with ease be spent in luxury, but it requires a mind to use it profitably. Both pleasure and profit may be gained by prudent and proper expenditure, and to show how even a limited income may enjoy great comfort at home (and there is, I hope you think, no place like home, and one's own home-fireside), I have ventured to bring before you at this time what can be done for one penny.

The penny itself is a matter which leads one into thought. The vastness of mind which has been brought to bear on the production of the coin is itself worthy of consideration. Before any coin can be sanctioned by the realm, it has to go through the ordeal of Her Majesty's Government, and after all has been done to the satisfaction of the authorities, a little bit of copper—though now, for the good of our pockets, mixed with an alloy—is made to minister to our wants in ways which I hope to lay before you as plainly and shortly as possible. First and foremost we must have that great and valuable thing heat, for without heat generated by fire we could have no penny. One of the first things required to produce this heat is wood. Now the wood must be grown,—trees attended to with care and at great cost. Years pass before they are either fit for beauty or use, yet, during the time of their growth, the smaller branches that are lopped off form just what is required to set on fire the coal and coke to produce the heat which is necessary for smelting and blast furnaces, for our own domestic fires, and various other uses. A faggot of these lopped branches can be bought for a penny. Having thus found out, as a beginning, one thing which can be obtained for a penny, let us go on to see what has to be attended to and encountered before this valuable coin can be made. Sums of money have to be spent, risks very great have to be entered into, and beautiful machinery constructed before it can be placed in our pockets. The mines of Cornwall have to be reached for both copper and tin—a matter of great cost to the pockets of speculators, and of anxiety to the minds of engineers, who lay themselves out to gain the material. Furnaces have to be built to smelt the ore and bring it into a workable condition. The Mint is then, after the metal is ready, called into requisition to produce a coin which, after all this labour and expense, is only a penny.

I come now to tell some of the things which can be accomplished and produced for a penny. One of the earliest publications of any note was the "Penny Magazine," which is endeared to my memory as having shown me the earliest of George Stephenson's great works—the Liverpool and Manchester Railway. This magazine has now passed away, but it has been amply replaced by others of equal merit, carrying out its principles of giving a sound and cheap literature to the people; it was a boon to all who cared for instruction, and at the same time had to take care of a penny. Now we have our daily papers at a penny, and of the 1711 newspapers issued (1876) in the United Kingdom, 808 are sold at this small price. Look at those papers, the "Telegraph," "Standard," and many others; are they not a light that has shone over our world, showing what man has been enabled to do for his fellows, in being able to disseminate the knowledge of what is transpiring over the world to their readers, both near and far off, and all for only one penny! Has this been done without labour? No. What has caused it but the earnest desire to know the events of daily life in as short a time as possible. I do not care to vouch for what I now say, but I should think that about 20,000 copies are thrown off of the "Daily Telegraph" in an hour, and these can be bought for one penny each. This penny's worth has cost a great amount of thought to bring about. Besides the various manufactures which are required for this result, the daily paper also brings to its aid the agriculturist as regards the paper; for though this was at first only made of rags, we now produce it from straw, and I have made it from thistles, whilst it has also been made from wood and other things. The rags, of course, were derived from agriculture in as far as flax required to be grown, but now the farmer gets his grain from the crop, and the straw left is made into paper—the chief agent in distributing through the world the thoughts of the learned in science, arts, literature, and politics. With what eagerness do we look for our paper in the morning, and with what pleasure do we pay our penny for it! A penny's worth with respect to this material does not stop here. Look at our beautiful and not costly decorations; see what a charming room we can show, produced by a wall-paper at a cost of one penny a yard. Some of these coloured decorations produce an eye-deception that quite, as the Scotch would say, "jumbles the judgment and confounds the understanding."

We have not done with luxuries, and I will now bring one before you that, like many others, if used aright, there is no harm in, and which I look upon as a means of keeping up social good-fellowship among all. I mean *smoking*. Now the use of tobacco in itself is harmless, but used in excess is not only dangerous, but acts as a poison. I like a pipe, but I find at the same time it is needful to have a light. The ingenuity of man has supplied my want and wish, and I can now get a light from an article which, to look at, seems only something black tipped with red. The labour required to produce this small box of lights, as it is called, is wonderful—the chemist, the wood merchant, the mechanician (and I am sorry to say, also the surgeon, from the deleterious effects of the phosphorus on the human frame), have all to bring their work to bear on the production of this most useful article. Yet, after all, it is sold and bought for one penny a box. Messrs. Bryant & May profess to save your houses from fire for this sum by using their matches, and I think they are right. Fire and heat are among our best friends, but are also dangerous enemies; and I am sure a penny spent on Bryant & May's matches is *well* spent. I do not wish to disparage other makers—far from it; but a match that will only ignite on the box is an article all householders should procure, not only for their own protection, but also for that of their neighbours.

A very striking instance of the value of a penny is set before us in that most wonderful system the penny-postage, the institution of which was a boon to the kingdom that cannot be too highly appreciated. It enables rich and poor alike to bring their thoughts and desires into communication with each other, and so relieve anxious cares in regard to the health and wealth, the joys and sorrows of friends in an easy manner. A penny stamp can convey all our requirements, whether for good or for evil, and many a large sum is now transmitted under its care. I have been told that as many as 60,000 letters have passed through the travelling post-office of the London and North-Western Railway in one night. How could this great correspondence ever have been carried on but for railways; and but for the foresight of Sir Rowland Hill this system might still have been in the background. It is clearly in my recollection when 1 s. 1-1/2 d. was the charge for a letter from London to Edinburgh, and that was for what was then called a *single* letter; now you may send as much as you like under a certain weight for one penny.

Travelling is now also a thing within the reach of all, for you can travel for one penny a mile, and this at a rate of speed that could not be done a few years ago. So much for railways.

Having begun with matters more especially affecting older people, it would be hard indeed to leave out the younger branches, and the means that are now employed not only for their comfort, but their amusement. Among other requirements for them we may class their toys. They are in a sense most needful, as well as useful, for our children, and from many of the ingenious toys now-a-days we can acquire a great deal of knowledge, useful to ourselves and of advantage to others. The beauty of their manufacture is a striking instance of the ingenuity of man as applied to small things, seeing that toys, so to speak, are only made for a few days' enjoyment, and are then almost certain to be broken. But for their short and transient existence what an amount of mental energy has been brought to bear—the fancy of the child has to be studied and provided for, in a way to please, gratify, and amuse, teaching the young idea how to shoot: all this for one penny. Look at the carts, horses, and other articles innumerable that are to be bought at the bazaars in London for a penny, and do they not bring before us in a striking manner what has been done for the benefit of the young. These toys, which only cost a penny, have caused many hard and anxious thoughts, are the means of giving work to thousands, and enabling these thousands to live an honest and happy life by furnishing a paying living, while at the same time they minister to the acquirements of those who when young require amusement. All this is done for a penny's worth; but how divided is this before the wonderful toy is produced! We have wood, iron, copper, tin, lead—I may say, all the metals, even the most precious (for gold is frequently used in the production of a toy that can be bought for a penny), are employed. Not only have these to be utilised, but they have first to be obtained—some by the growth of timber, others by mining, then by the heat of the furnace, then by hammer and workman, then by the chemist and colour-maker, then by the maker of the toy—many of these employed at large wages; and yet you receive for your children an article which not only gives instruction, but the greatest amusement, all for one penny.

An old saying, but a very true one, "Cleanliness is next to godliness;" and this brings us to a luxury which, though long known in France, has only been lately introduced here. This is the shoe-black. You come up to him, dirty from the mud of the streets of London, and in a very short time you have your boots shining for a penny. This penny's worth brings before us a large amount of thought before it can be earned and paid for. We have to begin with the farmer, who feeds the animal that, after we have eaten a good dish from and think no more of, yet furnishes the hair which is made into brushes by the brushmaker; the carpenter has to make the box to hold them; the blacking-maker also comes to the service; and the tailor to give the uniform red coat worn by the Shoeblack Brigade—yet after all this, you can get your boots blacked, and that well done, for one penny. Out of their earnings, at some stations the boys—so I was told a short time ago—have to pay 2s. 6d. a day for leave to stand at their station.

I have gone a long way on things that can be obtained for a penny, but I have not yet got to the greatest and most valuable—a thing which is to be obtained for even less than the widow's mite. It is this: "Come ye, buy and eat, without money and without price, for My word is meat indeed, and My word is drink indeed." Christ says this, and man cannot deny it. I am not going to preach a sermon, but as things have come before me, I have put them down.

Seeing what a penny can do, let us turn to some of the results. A penny a week at a school, and what can be gained? A child is educated to use the talents given him or her, so as to work out an honest living, and is there taught what it can do for the life that now is and that which is to come. The value of education is so great that it cannot be over-estimated. A young man I knew got into a railway workshop. He saved enough to go to Australia, where he has now made a large sum of money. He left this country with less than £50 in his pocket. He knew work and business, thanks to education, and had a determined desire to work his way. I wish it was so all over England, for I know in the Midland Counties every one will not leave home. You must leave home, at least for a season, if you wish to get on in the world. Nothing is to be gained in this world without striving for it. Here is work, but after death there is rest, but not till then. So, in conclusion, let me say, Let us all remember that while on earth it is a season for work. *Here is work*—work for the body, work for the mind, and, above all, work to prepare the soul for eternity. So that when we come to die, we may not only be able to look back on a life in which we have spent a penny aright, but be able to look forward to that life where is everlasting peace and joy, through Christ in God. And may our last words be—*Here was* work, but *there is* rest, through Christ our Saviour.

PAST AND PRESENT MEANS OF COMMUNICATION.

We may, I think, commence by saying, "Lord, so teach us to number our days that we may apply our hearts unto wisdom," for, as David says, "What is man that Thou art mindful of him, and the son of man that Thou visitest him? Thou makest him to have dominion over the works of Thy hands, and hast put all things in subjection under his feet." The difference of past and present means of communication are so great, that it is no easy task to enter into a discussion on the subject; but it leads one to gravely consider what is said in the 90th Psalm: "So teach us to number our days, that we may apply our hearts unto wisdom." To address an association such as I have now the honour and pleasure of doing, gives one a feeling of interest, as well as a feeling of responsibility, for as I have been kindly asked to close the course of lectures for this session, such an address is looked to in general with expectation. Do not hope for too much from me; but I trust that, when I have concluded, you will not be able to pay me the compliment an old Highland woman did to her minister on seeing him after church-service—"Ah, maister, this discoursing will never do, for I wasna weel asleep till ye were done." Having said this by way of introduction, I think it devolves upon me in some way first to explain what is the meaning of the subject of Communication. It may be briefly stated to be *a means to an end*—an intercourse or passage of either the body from one place to another, or of the thoughts of one person to another. And as I begin with the communication of the body, I cannot do better than name some of the methods by which communication is carried on, and shall commence with *Roads, Coaches, Railways, Canals*, and *Steamers*. Then, for mind, I will take *Books, Printing, Letters, Exhibitions*, and *Telegraphs*.

Our age has so advanced, that though Methuselah lived nearly one thousand years, yet he in his age did not live as long as we do now. See what science and art have done for us. We now do more in one day than could be done in a month some very few years ago; and, as far as travelling about the world is concerned, I can say that I have been from John-o'-Groat's House to Brighton, thence into Hertfordshire, thence back to London, from there to Edinburgh, thence to John-o'-Groat's, and here I am before you, without fatigue, or a thought that I should not be present in time. What has enabled us to do this but the determination of man to communicate with his fellow-men, and his thirst for the knowledge of what is doing in places where he, as an individual, could not be present. When there were no roads, it was no easy matter to move about, so the people remained at rest. But the Romans, a people who aspired to conquer the world, were not a people to sleep and let things stand still. They began the making of roads in Britain, and to them we owe the first of our greatness. They saw, as every wise man now sees, that the first thing to the improvement of land and property is easy communication, and facilities for bringing the things needed for the improvement of the land, and the means also of export for the produce. The earliest roads were, as we may say, right on end; and the Roman roads, as I hear, have borne the traffic of two thousand years. I hope I may say that even a Roman road would not bear the traffic of a town like Greenock for anything like that period of time, or I fear the commerce of this populous and most thriving town would be in a bad way. The great Telford and Macadam are the persons to be thanked for our beautiful system of road-making, and no person can, I am sure, deny the utility of their plans. As I said, roads are a means of communication for the body, and also for the mind; and therefore, now that their advantages are seen, we should strive to further their advance in all districts.

Coaches.—We come now to the means of communication on the roads for the body, and also for the mind, as both must go together—viz., the coach and the carriage or cart (for before the roads were made we had no coaches). In the first place, these carts or carriages were rude and heavy waggons, without springs or other comfort; but still they served to convey the body, and the mind that went with it at last discovered, by degrees, that conveyances could be constructed so as to cause less wear and tear on animal life. The result of time and labour has been the elegant constructions of the present day. The first hackney-coaches were started in London, A.D. 1625, by a Captain Bailey. Another conveyance for the body, the sedan-chair, was introduced first into England in 1584, and came into fashion in London in 1634. The late Sir John Sinclair was called a fool because he said a mail-coach would come from London to Thurso. I am glad to say that he *saw* it, and it opened up a communication for the body and mind that has worked wonders in the far North. We now have a railway.

Steam.—We proceed next to the grandest stage—or, as it is said in the North, "We took a start." What place have we to thank for this great start, but the very town in which I have the honour to give this closing address. Was not James Watt born here? The 19th January 1736 was a great day for England, Scotland, and the world at large, for that day brought into the world a man who, by his talents and by his observations of what others had done before him, was the means of bringing to a workable state that all-powerful and most useful machine, the steam-engine. The people of Greenock may well indeed feel proud of being citizens of a town that produced such a man; for though many places have given birth to great and valuable men, and persons who rendered the world vast and lasting service, yet, I may safely say, no one has surpassed James Watt in the benefits he has bestowed on the world, on its trade, its commerce, and its means of communication for both body and mind, as the producer of the steam-engine. There were not even coaches in his time, and his first journey to London was performed on horseback, a ten days' ride, very different to our ten or twelve hours now-a-days. His life and determination show what a man can do, both for himself and his fellow-men, and are a bright example to be followed by all those especially who belong to such associations as the one I now have the honour to address. He not only thought, but carried out his thoughts to a practical issue, and, though laughed at, he still stuck to his great work, and by his perseverance gave to the world one of its greatest boons, and certainly its greatest motive power—the steam-engine. The first use of the engine, as you well know, was the pumping of water. Rude were the machines made by Savory, Newcombe, and others, to achieve the desired end, but Watt, in his small room in the cottage at Glasgow, at last brought about a triumph that the world at large now feels and acknowledges. I will not go further into the history of a man so well known and appreciated, as his memory must be here, but will go on to say something briefly on the results of the operations of the mind over the material placed before it, to bring into form and make it practically useful for the advantage of man.

Steamers.—Greenock must see and value the great power at her disposal in the steam-ship. She has now her large building yards, and it was from her yards that, in 1719, the first ship—belonging to Greenock, and I believe built there—sailed for America, and from that time the trade increased rapidly. And I believe Glasgow launched the first Scotch ship that ever crossed the

Atlantic in 1718, only one year in advance of Greenock. The large building yards of Greenock bring into the town sums of money which, but for these yards, would go elsewhere, and deprive the community of many comforts, not to say luxuries. They are the means of carrying on the import and export trade of this thriving town in a way that could not otherwise have been done; famous as this place is for shipbuilding, spinning, and its splendid sugar-works. These latter you have indeed reason to be proud of, for there are few finer. The increase of importation of sugar is striking. In Britain in 1856, our imports of this article were 6,813,000 lbs., in 1865 it was 7,112,772 lbs. Though all this did not come to Greenock, yet from what you do in this trade, I think the word holds good that we as Scotchmen are sweet-toothed. You can now boast of a steam communication not only on the coast, but over the world. I had last year the pleasure of a cruise in the Trinity yacht "Galatea," and does not she speak volumes for what can be done by your citizens? for that vessel was built by Mr. Caird, and even the ship seemed to feel that she came from the beautiful Clyde. What a difference now to the time of Henry Bell in 1812, who first started a steamer for passengers on the Clyde! We have now in Great Britain 2523 steamers, registering no less than 766,200 tons. Have not these improvements shown what means of communication do for body and mind?

Railways.—Having said this much about steamers, I will turn for a short time to another means of communication for body and mind—I mean the railways. Are not they a striking advance in science, and the bringing to bear the power of mind to work on the material that has been provided for our use by an all-wise God? It is but a few years since, comparatively speaking, they came into existence, and yet, from the time of George Stephenson (and his perseverance largely aided to perfect the railway), see what vast sums of money have been spent, what magnificent and noble structures have been erected, and what speed has been obtained for the communication of body and mind. Instead of the thirty miles from Manchester to Liverpool in 1830, we now have in Great Britain and Ireland 13,289 miles of railway. The total capital paid in 1865 was £455,478,000, and this has largely increased since then. An idea may be formed of the difference of the rate of speed in travelling effected, both before and after the introduction of railways, by such facts as the following:—Two hundred years ago, King James's groom rode six days in succession between London and York, and a wonderful feat it was deemed; whilst now, the same distance is performed in five hours. About 1755 to 1760, the London and Edinburgh coach was advertised to run between these cities in fourteen days in summer, and sixteen in winter, resting one Sunday on the road. So much for the growing desire for speedy intercourse for mind and body.

Suez Canal.—There is an all-absorbing topic now before the public, and it is one that brings strikingly before us the thirst for communication of both body and mind to and from distant parts of our globe. It is one of deep importance to all who take an interest in the advancement of science—I mean the Suez Canal. The Red Sea cannot but be familiar to us all—a sea of the most profound interest, for there did the mighty Jehovah work one of His most stupendous miracles, when He brought the children of Israel out of Egypt, and at the same time destroyed Pharaoh and all his host. But in how different a manner did the Lord work! By a word He caused the waters to go back, leaving a wall on the right hand and on the left, so that the people of Israel went through on dry land. This was not all. Were not His chosen people accompanied by a pillar of fire to give light in the night season, and a cloud of thick darkness to prevent the Egyptians coming near them during the day? Does not this show that His mercy is over all His works? For after He had brought out His people with joy, and His chosen with gladness, He overthrew their enemies in the sea—in the same place where He had performed such wonders for the preservation of His people.

Often has the spot been crossed by our steamers; and though some may, and I trust do, bring to mind the stupendous miracle, yet it, like many other thing's, is regarded as a matter gone by. Here now we have the Red Sea brought under our notice in a most striking manner, and one that leads us not only to feel the greatness of the power of man over material things, but I trust it may also lead us to see our littleness when compared with Him who made us. We, that is the nations which brought about this great canal, have had to spend years and vast sums of money to carry out the end aimed at, and under the Divine aid it has been brought to a successful termination. But see what God did! Did the Almighty consult engineers, or take soundings and levels, or ask the laws of Nature if He could or would succeed? Nay,—one word was enough. He spake, and that was sufficient—the waters stood up in a heap. We, however, have succeeded in bringing the Red Sea and the Mediterranean into connection with each other—an achievement that strongly shows the determination of man. It is a boon, indeed, to the commerce of this country, and I hope also of many others, as by enabling ships to pass through, the transhipment of cargo is now done away with, and the distance to the other side of the globe reduced to its minimum. Engineers may truly be proud of the day that brought this great and noble work to a completion; and I trust they will thank the Lord who hath crowned their strenuous efforts with success.

Books.—Having got thus far as regards the conveyance of the body, we must now turn to the communication of the mind, and the thoughts of one individual as conveyed to another, and this leads one to speak of books. What are they but the means of communication of the thoughts of great men, and a distribution of those thoughts for the benefit of their fellows, by bringing before them matters of interest in the history of our own country and that of others. The great object to be looked to is the selection of our books—the variety is now so great; and I grieve to say (and I think I am right) that the sensational works of the present day have a tendency to lead the mind into a train of thought that is flippant and unsteady, and I would warn young people against them. When we look to such works as those of Sir Walter Scott, Macaulay, and many others of the same kind, we find food for the mind, the benefit of which cannot be over-estimated.

Printing.—The spread of knowledge through the world is indeed a boon which cannot be too highly extolled; but the thoughts of man could not thus have been circulated had it not been for the printing-press. See what science and art have done for us in this most perfect and beautiful machine! When we go only to one example, the "Times" newspaper, and consider the amount of information it circulates each day through the world, it strikes one forcibly what man has been allowed and enabled to do for the benefit of himself and his fellow-men. What we have brought the printing-press to, is shown in 20,000 copies of the "Times" being thrown off in one hour, and the advantage it has been to the advancement of literature in our now being able to buy such works as those of Sir Walter Scott for sixpence a volume.

Having gone so far, I must not detain you for more than a brief period. You have had such an able and interesting course of lectures given by men of high talent, that little remains for me except to close this course with congratulation to the Association in being able to procure those individuals to give their valuable time to this desirable object; for what in life is more interesting than the imparting the knowledge we may possess to others who desire to acquire it, seeing that there is no way in which moral and social intercourse is more advanced and developed. Still, before closing, I must ask for a short time to go into one or two other subjects. And first, I will take one of the greatest importance to the commerce of this country, and one that has shown what the mind has done for communicating the thoughts of one person to another at far distant places—I refer to the telegraph. The land is not only covered with wires, but even the vast depths of the great ocean are made to minister to our requirements. The world, we may say, is encircled with ropes, and instant communication has been the result. What has achieved these great results but the mind of man applied to science! And see in what a multitude of ways this application of mind has been made to work! What does it bring into play? Why, we have mining to produce the metal to make the wire; we have the furnace, hammers, and wire-drawing machines to produce the wire from the raw material. We have the forest then to go to for gutta-percha, for land poles, and for tar to preserve the cables. We have the farmer for our hemp. We have the chemist, we have the electrician, we have the steamer, and a great number of other requisites before the silent but unerring voice of the needle brings the thoughts of one man in America to another in this town in an instant of time. Accidents and mistakes will occur in the best-regulated works of all kinds, but I hope not often. One as to the telegraph I must tell that happened during the Indian Mutiny. The message meant to say that "The general won't act, and the troops have no head." The transformation was curious, namely, "The general won't eat, and the troops have cut off his head." If men would only consider well this grand achievement, they would be led indeed to say and feel, with all humility and thankfulness, that God has truly given him dominion over the works of His hands, and has put all things in subjection under his feet.

I had almost forgotten one other point of communication for mind, and, though at the risk of trying your patience, I must mention it, as its increase has been so large, and its advantages so manifold and untold. I mean the penny-postage. I am not going to enter into it at any length, but the increase of correspondence has been so large, that Sir Rowland Hill's name should not be left out of a lecture treating on subjects such as this one is intended to do. I will content myself by merely telling the increase of correspondence, and leave you to judge for yourselves as to its benefits. The number of letters in 1839, before the penny-postage, was 82,470,596, and in 1866 it was 597,277,616. Judge the difference!

Coming to the results of communication, I have one subject to bring before you, and as it has shown to such a large extent the benefits of international communication, I trust a few words on it may not be out of place. The subject is the great International Exhibitions that have been held in various countries in the last eighteen years. The first idea of holding such great exhibitions emanated from a man whose name cannot be held in too great estimation by all. Few men were gifted with such rare talents as he was, for there were few subjects, whether in science, literature, or art, that he was not intimately acquainted with. This man was the late Prince Consort. He conceived the idea that if the products of the various countries of the world could be brought together under one roof, the knowledge these would convey of the machinery, cultivation, science, literature, and arts practised in the various parts of the globe would tend to stimulate and advance the mind by showing that we had not only ourselves to look to, but that in a great measure we had to depend on others for the many blessings we now enjoy; and also lead us to see how needful to our prosperity and comfort is a constant communication with those who can communicate to us that knowledge which otherwise we could not obtain. Certainly the results have proved that he was right. Could anything have been more interesting or instructive to all than a visit to the Great Exhibitions of 1851 or 1862, or that of Paris in 1867. The public interest is at once shown when I tell you that 6,039,195 persons visited the latter, and the receipts in money were £506,100. There, all and every one had before him at a glance the subject most suited to his taste, with a full description of the country which produced it. From the largest machine, the heaviest ordnance, the most brilliant and precious stones, the finest silks, lace, furniture, carriages, the greatest luxuries for the table, and, in fact, everything needful for the use of man;—all were there, and all to be seen and studied by the inquiring mind, or to be regarded as very wonderful by those who went to the Exhibition as a sight. Few, I venture to say, ever left these buildings except wiser than when they entered. It could not fail to strike one, if one only gave it a moment's reflection, and asked himself, how has all this been brought about, but that it was the result of the communication of the minds of certain individuals with those of others, and by a concentration of the products of various countries to enlighten the mind as to the vast intelligence of the world at large.

In conclusion, I feel now that I have spoken long enough for any lecture, though I have not by any means exhausted the subject of communication of either past or present; but I should feel grieved if I exhausted your patience. All things, as we well know, must have an end, except that life to which we are looking forward and striving to gain, where we shall cease from our labours and be at rest. We have been endued by our Maker with thought and mind, talents to be used for our benefit, and not wrapped up in a napkin till our Lord's return, but to be placed out so as to bring in either the five or the ten talents. And, as you all know, we are answerable for the manner in which we employ them. May the result prove that we have used them aright.

The progress of means of communication of mind and body have been gradual but steady, and I think may be represented by human life from its childhood to manhood, as beautifully set forth in the 13th chapter of 1st Corinthians 11th verse, where it is said, "When I was a child, I spake as a child; I understood as a child, I thought as a child; but when I became a man, I put away childish things." Is not this very much in keeping with our growth in communication? At first it was small, and we were content to hear of what others were engaged in without regard to time, as one day earlier or later was of little consequence. But now we are not children, but are become men in our interests and thirst for communication with each other. What should we say if we found the Express, as was written on the boy's post-bag, busily engaged in a game of bowls on the road, regardless of the loss of time or money thereby occasioned? I think we should be inclined to write to the papers.

The results of communication are manifold, and day by day they are brought before us in a manner which shows the untiring wish of man for improvement both in social and commercial interests. These results are strikingly shown in the various subjects I have endeavoured to bring before you. Each and all of them are subjects for thought. What should we now be without, I may say, any one of them?

A well-regulated mind is the most desirable of all acquirements, and I know no better means of gaining this than by meetings of such institutions as this. Here you have intercourse with your friends, and you can gain from one another by friendly intercourse stores of knowledge, that to search for as individuals would take away much more time than you could by any means devote, and at the same time attend to the business of your calling. Here you have the means of amusement as well as of gaining sound information, and I trust no one here will ever have cause to regret the day when he came to associate with his friends, and hear what others could communicate, for "in the multitude of counsellors there is wisdom."

THE STEAM-ENGINE.

The many varieties of the world's manufactures—one might almost call them wonders—are now so numerous, that to bring any particular one in a single form before this meeting is a matter of no easy nature. To-night, however, I have ventured to single out, and have the pleasure of bringing before you, the steam-engine, as the prime mover at present of our workshops and manufactories, as also the grand motive power of our railways, now so different from the time when the great Stephenson was said to be mad, because he thought it possible to drive a train at fifteen miles an hour. For the first serviceable use of this grand machine we are indebted to the great James Watt. He it was who first wrought it so as to be under the useful and entire control of man, from what it was in the time of Hero of Alexandria, about 120 years before Christ. Our engineers have, since Watt's time, improved upon it year by year, till at the present day, instead of having to go in a mail-coach from London to Edinburgh, which formerly took fifty hours, we now go in the express train in ten, a distance of 420 miles. If beyond this ten hours, we grumble, and ask guards, porters, &c., at the various stations, "What has made the train so late to-day?" forgetting that just before the railways were first opened, the great Stephenson was urged not to say too much as to the supposed power of the locomotive, in case the cause of railways might be damaged. This was only some forty years ago, and it shows us how times are changed, for in the present day we consider thirty miles an hour anything but a fast train.

The history of the steam-engine is a subject on which so much has been written in books and magazines now before the public, that what I am about to offer, though pretending nothing new, yet I hope may be looked upon as containing something useful as well as instructive, both to the practical and the amateur mechanic. I shall therefore, in as small a compass as possible, trace the steam-engine from its first and early stages up to its present perfect state as our grand motive power. The first mention made of the vapour of water, as formed by the action of heat upon it, is found to be as far back as 120 B.C., when one Hero of Alexandria employed this vapour for the purpose of driving a machine. It is a well-known fact that when water is brought up to a certain degree of heat, called the boiling-point, that it sends forth a vapour, the elastic properties of which, when in an open vessel, are not perceived—as, for instance, in a common pan—yet if the vessel is closed or shut up at the top, you will find that the vapour acquires such a degree of elastic force, that, if not allowed to escape by fair means, it would soon make a way or vent for itself by bursting whatever vessel it was contained in. Steam is thus highly elastic, but when separated from the fluid out of which it is generated, it does not possess a greater elastic force than the same quantity of air. If, for example, a vessel is filled with steam only at 212°, it may be brought to a red heat without fear of bursting; but if water is also in the vessel, each additional quantity of heat causes a fresh quantity of steam to be generated, which adds its elastic force to that of the steam already in the vessel, till the constantly accumulating force at last bursts the vessel.

This elastic vapour is called steam, and it is by this that that most beautiful machine, the steam-engine, is driven. As you all know, by this vapour or air—for it is invisible till it loses part of its heat—enormous power is obtained in a small compass, and the labour of man reduced to nothing compared with former ages. Many men laboured to perfect machinery to be worked by this vapour of water, and many came near the mark; but it remained for the great Watt, at the Soho Works, Birmingham, to bring the engine to its useful and working state, for though discovered as a motive power 120 B.C., it was yet reserved for this truly great man to be what may be termed the inventor of the steam-engine.

In 120 B.C., Hero of Alexandria made a machine to be driven by steam. It consisted of a hollow sphere into which the steam was admitted; projecting from the sphere were two arms, from which the steam escaped by three holes on the side of *each* arm opposite to that of the direction of its revolution, which, by removing the power from off the one part of *each* arm, caused it to revolve in the direction opposite to that of the hole that allowed the steam to escape. This kind of engine has been for some years in use by Mr. Ruthven of Edinburgh. There are others who have followed very closely on Hero's plan in more ways than one; for instance, it is the common Barker's mill, though with this difference, that his mill is driven by water instead of steam: Avery, also, made a steam-engine almost exactly the same. I may here, perhaps, just be allowed to mention what a little water and coal will produce, as it will show at once from whence our power is derived. "A pint of water may be evaporated by two ounces of coal; in its evaporation it swells to 216 gallons of steam, with a mechanical force equal to raising a weight of thirty-seven tons one foot high." A pound of coal in a locomotive will evaporate about five pints of water, and in their evaporation these will exert a force equal to drawing two tons on a railway a distance of one mile in two minutes. A train of eighty tons weight will take 240 passengers and luggage from Liverpool to Birmingham and back, each journey about four and a quarter hours; this double journey of 190 miles being effected by the combustion of one and a half tons of coke, worth about twenty-four shillings. To perform the same work by common road would require twenty coaches, and an establishment of 3800 horses, with which the journey would be performed each way in about twelve hours, stoppages included. So much for the advantages of steam.

The Romans are supposed to have had some knowledge of the power of steam. Among amusing anecdotes, showing the knowledge the ancients had of steam, it is told that Anthemius, the architect of Saint Sophia, lived next door to Zeno. There existed a feud between them, and to annoy his neighbour, Anthemius had some boilers placed in his house containing water, with a flexible tube which he could pass through a hole in the wall under the floor of Zeno's dwelling; he then lit a fire, which soon caused steam to pass through the tube in such a quantity as to make the floors to heave as if by an earthquake. But to return. We next come to Blasco de Garay (A.D. 1543), who proposed to propel a ship by the power of steam. So much cold water seems to have been thrown on his engine, that it must have condensed all his steam, as little notice is taken of it except that he got no encouragement. We find that it has also been used by some of the ancients in connection with their deities. Rusterich, one of the Teutonic gods, which was found in an excavation, proves how the priests deceived the people. The head of this one was made of metal and contained a pot of water. The mouth and another hole in the forehead being stopped by wooden plugs, a fire of charcoal was lighted under this pot of water, and at length the steam drove out the plugs with a great noise, and the god was shrouded in a mist of steam which concealed him from his astonished worshippers.

In 1629, Giovanni Branca of Loretto in Italy, an engineer and architect, proposed to work mills and other machinery by steam blowing against vanes, much in the same way as water does in turning a wheel. The waste of steam in such a plan is so obvious, that it is not to be wondered at that it did not produce any great results, as we all know that the moment we let steam out of his case, the case is all up with him, and he dies a natural death. He is a most delicate yet powerful agent, and requires to be kept warm in all weathers—this fact does not seem to have struck Mons. Branca when he let him out of his boiler.

The next person we come to, and perhaps the first of any note, is the Marquis of Worcester in 1663 (died 1667). He was a man who seems, as far as history tells us, to have taken a great interest in furthering the advancement of steam. He was not contented with one invention, but published a book entitled "A Century of Inventions," and in this work he describes a means of raising water by the pressure of steam. The Marquis appears to have been a politician as well as an inventor, as we find he was engaged on the side of the Royalists in the Civil Wars of the Revolution, lost his fortune and went to Ireland, where he was imprisoned. Escaping to France, from thence he returned to London as a secret agent of Charles II., but was detected and imprisoned in the Tower, where he remained till the Restoration, when he was set at liberty. One day, while in prison, he observed the lid of the pot in which his dinner was being prepared lifted up by the vapour of the water boiling inside. Reflecting on this, he turned his mind to the matter, and thought that this vapour, if rightly applied, might be made a useful moving power. He thus describes his invention in his 68th Article: "I have contrived an admirable way to drive up water by fire, not by drawing or sucking it upwards, thirty-two feet. But this way hath no bounds, if the vessels be strong enough." He then goes on to say, that "having a way to make his vessels, so that they are strengthened by the force within, I have seen the water run like a constant stream forty feet high. One vessel rarified by fire driveth forty of cold water, and one being consumed, another begins to force, and refill with cold water, and so on successively, the fire being kept constant.

The engineman having only to turn two cocks, so as to connect the steam with the one or the other vessel."

In this engine, if it can be called an engine, we see that the Marquis had a good idea of the power of steam, but he had none, you will observe, as to the action of the condensation which would immediately take place when the steam from the boiler was brought into contact with the cold water to be raised. Therefore this plan would be most expensive, on account of the great loss of steam by condensation. It was, however, quite able to produce the effect, though only equal to raising 20 cubic feet of water, or 1250 lbs., one foot high by one pound of coal, or about the two-hundredth part of the effect of a good steam-engine. After this, of course, it proved of no avail; but still we may say that the Marquis of Worcester was among the first who tried to make, and did do so, steam a moving power.

Our next is Denys Papin (died 1710), a native of Blois, in France, who was mathematical professor at Marpurg. To him is due the discovery of one of the qualities of steam—its condensation, so as to produce a vacuum, to the proper management of which our modern engines owe much of their efficacy. Papin seems to have been the first who conserved the idea of the cylinder and piston, which he made to act on atmospheric principles—that is to say, he took a cylinder with a piston moving up and down in it, and found that by removing the air from under the piston in the cylinder, that the pressure of the atmosphere would drive it down to the bottom of the cylinder: this he performed by admitting steam, and then condensing it rapidly, so causing the required vacuum. The pressure of the atmosphere is as near as may be 16 lbs. on every square inch of surface on the globe: this is obviously the weight of the columns of air extending from that square inch of surface upwards to the top of the atmosphere. This force is thus measured: Take a glass tube 32 inches long, open at one end and closed at the other; provide also a basin full of mercury; let the tube be filled with mercury and inverted into the basin. The mercury will then fall in the tube, till it gets to that height which the atmosphere will sustain. This is nothing more than the barometer used in all our houses. If the action of the tube be equal to a square inch, the weight of the column of mercury in the tube would be exactly equal to the weight of the atmosphere on each square inch of surface. Thus Papin discovered a great step in the steam-engine, though it was not much acted on for some years; he was also the first who proposed to drive ships with paddles worked by steam.

We now come to Thomas Savory, who got a patent in 1698 for a method of condensing steam to form a vacuum. Savory describes his discovery in this way:—Having drank a flask of wine at a tavern, he flung the empty flask on the fire, and then called for a basin of water to wash his hands. A little wine remained in the flask, which of course soon boiled, and it occurred to him to try what effect would be produced by putting the mouth of the flask into the cold water. He did this, and in a moment the cold water rushed up and filled the flask, this being caused by the steam being condensed and leaving a vacuum, which Nature abhors, and rather than permit this the water rushed up and took the place formerly occupied by the now condensed steam. We see by this in how simple a way great ends are produced, and in the age in which this happened, the result may be indeed be said to have produced a great end. The engine of Savory was used for some years as a machine to raise water. The principle of his engine was just as I have stated, and consisted of two cases and other various parts, and this engine possessed advantages over that of the Marquis of Worcester in sucking up the water as well as forcing.

Savory's engine consisted of two steam vessels connected to a boiler by tubes; a suction pipe, or that pipe which leads from a pump of the present day to the well, and communicating with each of the steam vessels by valves opening upwards; a pipe going from these steam vessels to any required height to which the water is to be raised. The steam vessels were connected to this pipe by other valves, also opening upwards, and by pipes. Over the steam vessels was placed a cistern, which was kept filled with *cold* water. From this proceeded a pipe with a stopcock. This cistern was termed the condensing cistern, and the pipe could be brought over each steam vessel alternately from the boiler. Now, suppose the tubes to be filled with common air, and the regulator placed so that one tube and the boiler are made to communicate, and the other tube and the boiler closed, steam will fill one of the steam vessels through one tube; at first it will condense quickly, but erelong the heat of the steam will impart its heat to the metal of the vessel, and it will cease to condense. Mixed with the heated air, it will acquire a greater force than the air outside the valve, which it will force open, and drive out the mixture of air and steam, till all the air will have passed from the vessel, and nothing but the vapour of water remain. This done, a cock is opened, and the water from the cistern is allowed to flow over the outside of the steam vessel, first having stopped the further supply of steam from it; this produced the immediate condensation of the steam contained in it, by the temperature being brought down again by the cold water, and the condensation thus produced caused a vacuum inside the vessel. The valve will then be kept closed by the atmosphere outside, and the pressure of the air on the surface of the water in the well or reservoir will open another valve, force the water up the pipe, till, after one or two exhaustions—if I may so term it—it will at last reach the second vessel. Thus far the atmosphere has done all the work, but at last the water fills the vessel, and then comes the forcing point. Now the power of the steam itself is used to drive the water up the pipe. The steam is again let into the vessel, now filled in whole, or at least in great part, with water; at first it will, as before, condense rapidly, but soon the surface of the water will get heated, and as hot water is lighter than cold, it will keep on the surface, and the pressure of the steam from the boiler will drive all the water from the vessel up the pipe. When it is empty the cock is again opened, and the steam, which the vessel by this time only contains, is again condensed, and the same process which I have just described is again commenced and carried out, thus making Savory's engine a complete pump by the aid of the vapour of water as raised by fire.

Savory had the honour of showing this engine to His Majesty William III. at Hampton Court Palace, and to the Royal Society. He proposed the following uses, which perhaps may as well be mentioned, as they show how little was then known of the real value of the power of steam:—1. To raise water to drive mill-wheels—fancy erecting a steam engine now, of say fifty horse-power, to raise water to turn a wheel of say thirty; 2. To supply palaces and houses with water; 3. Towns with water; 4. Draining marshes; 5. Ships; 6. Draining mines. There is one more thing I may mention as curious, that though the steam he used must have been of a high pressure, he did not use a safety-valve, though it had been invented about the year 1681 by Papin. The consumption of fuel was enormous in Savory's engine, as may easily be perceived from the great loss of steam by condensation. Nevertheless, it was on the whole a good and a workable engine, as we find the following said of it by Mr. Farey:—"When comparison is made between Captain Savory's engine and those of his predecessors, the result will be favourable to him as an inventor and practical engineer. All the details of his invention are made out in a masterly style, so as to make it a real workable engine. His predecessors, the Marquis of Worcester, Sir S. Morland, Papin, and others, only produced outlines which required to be filled up to make them workable."

I must not detain you much longer before I proceed to the great Watt, but I will just name Newcomen, who invented an engine with a cylinder, and introduced a beam, to the other end of which he fixed a pump rod like a common or garden pump. He made the weight of the pump and beam to lift the piston, and then let the steam enter below the piston and condensed it by a jet of water, thus causing a vacuum, when the pressure of the atmosphere drove the piston from the top to the bottom of the cylinder and lifted the pump rods in the usual way. There were various cocks to be opened and shut in the working of this engine for the right admission of steam and water at the required moments, a task which was performed by boys who were termed cock-boys. I will now mention an instance which, though in practice not to be imitated, yet was one of those happy accidents which sometimes turn out for the best. One of these boys, like many, more fond of play than work, got tired of turning these cocks day by day, and conceived the idea of making the engine do it for itself. This idle boy—we will not call him good-for-nothing, as he proved good for a great deal in one way—was named Humphrey Potter, and one day he fixed strings to the beam, which opened and shut the valves, and so allowed him to play, little thinking this was one of the greatest boons he could possibly have bestowed on the world at large, for by so doing he rendered the steam-engine a self-acting machine.

We now come to a period which was destined to advance the cause of steam to a far greater extent—in fact, the time which rendered the steam-engine the useful and valuable machine it now is. This is the time of James Watt. This great man, be it said to the credit of Scotland, was born in Greenock, on the Clyde, on the 19th January 1736. His grandfather was a farmer in Aberdeenshire, and was killed in one of the battles of Montrose. His father was a teacher of mathematics, and was latterly chief magistrate of Greenock. James Watt, the celebrated man of whom I now speak, was a very delicate boy, so much so, that he had to leave school on account of his health, and was allowed to amuse himself as he liked. This he did in a scientific way, however, as an aunt of his said to him one day: "Do you know what you have been doing? You have taken off and put on the lid of the teapot repeatedly; you have been holding spoons and saucers over the steam, and trying to catch the drops of water formed on them by it. Is it not a shame so to waste your time?" Mrs. Muirhead, his aunt, was little aware that this was the first experiment in the way which afterwards immortalised her nephew.

In 1775 Watt was sent to London to a mathematical instrument maker, but could not stay on account of his health, and soon afterwards came back to Glasgow. He then got rooms in the College, and was made mathematical instrument maker to the University, and he afterwards opened a shop in the town. He was but twenty-one years of age when he was appointed to this post in the College, and his shop became the lounge of the clever and the scientific. The first time that his attention was directed to the agency of steam as a power was in 1734, when a friend of his, Mr. Robinson, who had some idea of steam carriages, consulted him on the subject,—little is said of this, however. In 1762 Watt tried some experiments on high-pressure steam, and made a model to show how motion could be obtained from that power; but did not pursue his experiments on account of the supposed danger of such pressure. He next had a model of Newcomen's engine, which would not work well, sent him to repair. Watt soon found out its faults, and made it work as it should do. This did not satisfy him, and setting his active mind to work, he found in the model that the steam which raised the piston had of course to be got rid of. This, as a natural consequence, caused great loss of heat, as the cylinder had to be cooled so as to condense the steam; and this led him at last, after various plans, to adopt a separate vessel to condense this steam. Of course, if you wish to save fuel, it is necessary that the steam should enter a heated cylinder or other vessel, or else all the steam is lost,—or in other words, condensed,—that enters it, until it has from its own heat imparted so much to the cylinder as to raise it to its own temperature, when it will no longer condense, and not till then does it begin to exert its elastic power to produce motion. This was the great object gained by James Watt, when, after various experiments, he gave up the idea altogether of condensing steam in its own or working cylinder, and then made use of a separate vessel, now called the condenser.

The weight of steam is about 1800 times less than water. I may here perhaps mention also that water will boil at 100 degrees Fahr. in vacuo, whereas in atmosphere it takes 212 degrees to boil. There is also a thing perhaps worth knowing to all who wish to get the most stock out of bones, &c., that if they are boiled in a closed vessel, that is to say, under a pressure of steam, a very large increase in quantity of the stock will be produced, because the heat is increased. A cubic inch of water, evaporated under *ordinary* atmospheric pressure, will be converted into a cubic foot of steam; and a cubic inch of water, evaporated as above, gives a mechanical force equal to raising about a ton a foot high.

The next great improvement of Watt, in addition to the condenser, is the air-pump, the use and absolute necessity for which you will understand when I explain its action. Watt first used it for his atmospheric engine. The piston of this engine was kept tight by a flow of oil and water on the top, which tended to make the whole a troublesome and bad-working machine. The cold atmosphere, as the piston went down, of course followed it and cooled the cylinder. On the piston again rising, some steam would of course be condensed and cause waste. If the engine-room could be kept at the heat of boiling water, this would not have been the case, but the engineman who could live in this heat would also require to be invented, and so this had to be given up. Watt's next and most important step was the one which brings us to talk of the steam-engine as it now is in the present day. This important step was the idea, of making the steam draw down the piston, as well as help to drive it up; in the first engines it was raised by the beam, and steam used only to cause a vacuum, so as to let the air drive it down. All before this had been merely steps in advance, like those of children, who must walk before they can run; so was it with the steam-engine. It was uphill work for many years, and the top of the hill cannot be said to have been readied till Watt worked out this grand idea. The first engine could only be called atmospheric; now it was destined to become in reality a steam-engine. Time would fail were I to attempt to go into any details of all the experiments through which Watt toiled to bring his ideas to perfection—enough to say that he did so; and I trust you will be able, through the description I will endeavour to give, to understand how well his labour was bestowed, and how beautiful the result has proved for the benefit of the world at large. In 1773, Watt removed to Soho, near Birmingham, where a part of the works was allotted to him to erect the machinery necessary to carry out his inventions on a grand scale.

We must now proceed to some of the useful points of the engine, all I have before mentioned simply relating to the inventors and improvers; but having brought it so far, I may now, I think, proceed further. The first use of the steam-engine was simply to raise water from mines, and for long it was thought it could be used for nothing else; so much so, that it was at one time used to raise water to turn wheels and thus produce motion. One of its first uses after it became a really useful machine was to propel ships, though many a weary hour was spent to bring it to this point. There is a very pretty monument on the Clyde, dedicated to Mr. Bell, who I believe was the first person who successfully brought steamers to work on its waters. The first who used steam for ships was Mr. James Taylor, in conjunction with Mr. Miller of Dalswinton. The danger of the fire-ship took such hold on people's minds that it was with great toil and difficulty they were persuaded to venture on the face of the waters in such dangerous and unseamanlike craft. But go to Glasgow Bridge any day, and you will see how time has overcome fear and prejudice, for our ocean is covered with steamers of all sizes. It is not many years ago since it was said that steamers could never reach America; this has given way to proof, and even Australia has been reached by steam. I know of a steamer building which could carry the whole population of this place and not be full; she is 680 feet or 226 yards long, and a large vessel would hang like a boat alongside her.

The first attempt at giving motion by steam to ships was of course only in one way—by a ratchet at the end of a beam, at one moment driving and the next standing still. This was on account of the engine being only in power one half of the stroke; but by the double-acting engine being introduced, and the steam acting both ways, it became at last a steady mover (without the aid of two or three cylinders, as in the first engines, one to take up the other as the power was given off), by a ratchet on the end of a beam or else a chain. This acted on the shaft which moved the paddles. It is to Watt that we are indebted for the crank and direct action, so as to give a circular motion to the wheels.

We find in 1752 a Mr. Champion of Bristol applied the atmospheric engine to raise water to drive a number of wheels for working machinery in a brasswork, in other words, a foundry. Also, in Colebrokedale, steam-engines were used to raise water that had passed over the wheel, so as to save water. All these plans have, however, now passed by, like the water over the wheel, and we now have the engine the prime mover—the double action of the steam on the piston, this acting on the sway beam, and the beam on the crank, which, by the assistance of the fly-wheel on land or fixed engines, gives a uniform motion to the machine. All these have now enabled us to apply the engine as our grand moving power. One great and important point in the engine is the governor, and the first modes of changing the steam from the top to the bottom of the cylinder were cumbrous, till the excentric wheel was devised.

Boilers also have to be attended to—these were at first rude and now would be useless. They were unprovided with valves, gauge-cocks, or any other safety, all of which are now so well understood that nothing but carelessness can cause a blow-up. One of the greatest causes of danger is that of letting there be too little water in the boiler, and thus allowing it to get red-hot, when, if you let in water, such a volume of steam is generated that no valve will let it escape fast enough. Force or feed pumps are also required to keep the water in the boiler at a proper height, which is ascertained by the gauge-cocks. Mercury gauges for low pressure act according to the pressure of the atmosphere; high-pressure boilers of course require a different construction, as the steam is greater in pressure than the air.

Having got so far in my subject, I think before concluding I must devote a short time in showing the first steps of the locomotive; the more so, as I am speaking to those who are so largely engaged in the daily working of that now beautifully perfect machine. Various and for a time unsuccessful experiments were made to bring out a machinery or travelling engine, as it was first called. A patent was taken by a Mr. Trevethick for a locomotive to run on common roads, and to a certain extent it did work. An amusing anecdote is told of it. In coming up to a toll-gate, the gatekeeper, almost frightened out of his seven senses, opened the gate wide for the monster, as he thought, and on being asked what was to pay, said "Na-na-na-na!" "What have we got to pay?" was again asked. "No-noth-nothing to pay, my dear Mr. Devil; do drive on as fast as you can!" This, one of the first steam carriages, reached London in safety, and was exhibited in the square where the large station of the London and North-Western Railway now stands. Sir Humphrey Davy took great interest in it, and, in writing to a friend, said: "I shall hope soon to see English roads the haunts of Captain Trevethick's dragons." The badness of roads, however, prevented its coming into general use.

Trevethick in 1804 constructed a locomotive for the Merthyr and Tydvil Rail in South Wales, which succeeded in drawing ten tons at five miles an hour. The boiler was of cast-iron, with a one-cylinder engine, spur gear and a fly-wheel on one side. He sent the waste steam into the chimney, and by this means was very nearly arriving at the blast-pipe, afterwards the great and important discovery of George Stephenson. The jumping motion on the bad roads, however, caused it constantly to be dismounted, and it was given up as a practical failure, being sent to work a large pump at a mine. Trevethick was satisfied with a few experiments, and then gave it up for what he thought more profitable speculations, and no further advances were made in locomotives for some years. An imaginary difficulty seems to have been among the obstacles to its progress. This was the supposition that if a heavy weight were to be drawn, the grip or bite of the wheels would not be sufficient, but that they would turn round and leave the engines stationary, hence Trevethick made his wheels with cogs, which of course tended to cause great jolts, as well as being destructive to the cast-iron rails.

A Mr. Blenkinsop of Leeds patented in 1811 a locomotive with a racked or toothed rail. It was supported on four wheels, but they did not drive the engine; its two cylinders were connected to one wheel behind, which was toothed and worked in the cog-rail, and so drove the engine. It began running on Middleton Coal Rail to Leeds, three and a quarter miles, on the 12th August 1812, and continued a great curiosity to strangers for some years. In 1816 the Grand Duke Nicholas of Russia saw this engine working with great interest and expressions of no slight admiration. An engine then took thirty coal-waggons at three and a quarter miles in an hour.

We next come to Messrs. Chapman of Newcastle, who in 1812 tried to overcome the supposed want of adhesion by a chain fixed at the ends of the line and wound round a grooved drum driven by the engine. It was tried on the Heaton Rail near Newcastle, but was found to be so clumsy that it was soon abandoned. The next was a remarkable contrivance—a mechanical traveller to go on legs. It never got beyond its experimental state, and unfortunately blew up, killing several people. All these plans show how lively an interest was then being taken in endeavouring to bring out a good working locomotive. Mr. Blackett, however, persevered hard to perfect a railway system, and to work it by locomotives. The Wylam waggon-way, one of the oldest in the North, was made of wooden rails down to 1807, and went to the shipping-place for coals on the Tyne. Each chaldron-waggon was originally drawn by a horse with a man in charge, only making two journeys in the one day and three on the following, the man being allowed sevenpence for each journey. This primitive railway passed before the cottage where George Stephenson was born, and was consequently one of the first sights his infant eyes beheld; and little did his parents think what their child was destined to work out in his day for the advancement of railways. Mr. Blackett took up the wood and laid an iron plate-way in 1808, and in 1812 he ordered an engine on Trevetbick's principle. It was a very awkward one, had only one cylinder of six inches diameter, with a fly-wheel; the boiler was cast-iron, and was described by the man who had charge of it as having lots of pumps, cog-wheels, and plugs. It was placed on a wooden frame with four wheels, and had a barrel of water on another carriage to serve as a tender. It was at last got on the road, but would not move an inch, and her driver says:—"She flew all to pieces, and it was the biggest wonder we were not all blown up." Mr. Blackett persevered, and had another engine, which did its work much better, though it often broke down, till at length the workmen declared it a perfect plague. A good story is told of this engine by a traveller, who, not knowing of its existence, said, after an encounter with the Newcastle monster working its great piston, like a huge arm, up and down, and throwing out smoke and fire, that he had just "encountered a terrible deevil on the Hight Street road."

We now come to George Stephenson, who did for the locomotive what Watt did for our other steam-engines. His first engine had two vertical cylinders of eight inches diameter and two-feet stroke, working by cross-heads; the power was given off by spur-wheels; it had no springs, consequently it jolted very much on the then bad railways; the wheels were all smooth, as Stephenson was sure the adhesion would be sufficient. It began work on the 25th July 1814, went up a gradient of one in 450, and took eight waggons with 30 tons at four miles an hour. It was by far the most successful engine that had yet been made. The next and most valuable improvement of Stephenson was the blast-pipe—by its means the slow combustion of the fire was at once overcome, and steam obtained to any amount. This pipe was the result of careful observation and great thought. His next engine had horizontal connecting rods, and was the type of the present perfect machine. This truly great man did not rest here, but time would fail, as well as your patience, if I were to proceed further. Enough to say, that he afterwards established a manufactory at Newcastle, and time has shown the result and benefit it has proved to the whole world at large. A short time before the Liverpool and Manchester Railway was opened, Stephenson was laughed at because he said he thought he could go thirty miles an hour, and was urged before the House of Commons not to say so, as he might be thought to be mad. This I have from person who knew the circumstances. Nevertheless, at the trial, I believe the "Rocket" did go at the rate of thirty miles an hour, to the not small astonishment of the world, and especially to the unbelievers in steam as a land agent. The stipulation made was that trains were to be conveyed at the rate of twelve miles an hour.

In our present perfect engines, the coke or fuel consumed per mile is about 18 lbs. with a train of 100 tons gross weight, carrying 250 passengers. A first-class carriage weighs 6 tons 10 cwts.; a second-class, 5 tons 10 cwts., each with passengers; a Pullman car weighs about 30 tons. Our steamers consume 5 lbs. of coal per horse-power in one hour. And last, not least, one of the greatest improvements we have had in steam propulsion is the screw. Again, I may also name the great advantage derived from steam by our farmers in thrashing out grain. The engines principally used in farm-work are what are termed high-pressure, or of the same class as the locomotive. The great saving in cost in the first place, the simplicity and ease of action in the second, and the small quantity of water required to keep them in action, are all reasons why they should be preferred. The danger in the one, that is, the high-pressure, over the condenser, is very small, and all that is required is common care to guard against accidents. Steam being a steady power, is much to be preferred to water, as by its constant and uniform action the tear and wear of machinery is much diminished, and of course proportionate saving made in keeping up the mill or any other machinery.

Having now, to the best of my power, so far as a single lecture will permit, brought the steam-engine from 120 B.C. to the present time, it only remains for me to say, that it shows how actively the mind of man has been permitted to work to bring it to perfection by the direction of an all-wise Providence, "who knows our necessities before we ask, and our ignorance in asking." A traveller by rail sees but little of the vast and difficult character of the works over which he is carried with such ease and comfort. Time is his great object. No age of the world has conquered such difficulties as our engineers have had to deal with, and the result is now before the eye of every thinking traveller. Our engineers were at first self-taught, and many a self-taught man has had reason to rejoice in the time he spent in his education. Of these men we have examples in Brindley, who was at first a labourer and afterwards a millwright; Telford was a stone-mason; Rennie a farmer's son apprenticed to a millwright; and George Stephenson was a brakesman at a colliery. Perseverance with genius, and a determination to overcome, made them the great men they were. That you may so persevere and strive is the earnest wish of him who has this evening had the great pleasure of giving you this lecture, and who feels so greatly obliged to you for the very patient hearing you have given him.

ON ATTRACTION.[B]

Gravitation.—Attraction, which may be illustrated by the effect a magnet has on a piece of iron, may be viewed generally as an influence which two bodies, say, exert on each other, under which, though at a distance, they tend to move towards each other till they come into contact. The force by which a body has weight, and, when free, falls to the ground, is of this nature; and it is called, from *gravis*, "heavy," the gravitating force of the earth, because it causes weight, and because, though emanating in a small degree from the falling body, it is mainly exerted by the earth itself. It is under the action of gravity that a pendulum oscillates: it is by that unseen influence it begins to sway alternately downward and upward as soon as it is moved to a side; and it is only because it is withheld by the rod that the ball or bob keeps traversing the arc of a circle and does not fall straight to the earth.

All material substances, however small, and however light, buoyant, and ethereal they may seem, are subject to this force: the tiniest speck in a sunbeam and the most volatile vapour, equally with the heaviest metal and the hugest block, the particles of bodies as well as the bodies themselves. The rising of a balloon in the air may seem an exception to this law; but it is not so; for the balloon rises, not because the particles of the gas with which it is inflated are not acted upon by the earth's attraction, but because the air outside being bulk for bulk heavier than the air inside, its particles press in below the balloon and buoy it up, until it reaches a stratum of the atmosphere where, the pressure being less, the air outside is no heavier than the air within—a fact which rather proves than disproves the universal action of gravitation; because the greater weight of the air in the lower strata of the atmosphere is due to the pressure of the air in those above, and the balloon ceases to ascend because it has reached a point where the air outside is the same weight as the air within, and the weight in both cases is caused by the attraction of the earth.

And not only is the force of attraction universal, it is the same for every particle; for though this may seem to be contradicted by the fact that some bodies fall faster to the ground than others, that fact is fully accounted for by the greater resistance which the air offers to the falling of lighter bodies than to the falling of heavier. A particles of bodies, and all bodies, tend to fall with the same velocity, and, in fact, all do; for though, for the reason just stated, a feather will take longer to reach the ground than an ounce of lead, an ounce of lead will fall as fast as a hundredweight. And that it is the resistance of the air, and not any diminution in the power of attraction, which causes the feather to lag behind, may be proved by experiment; for if you let a feather and a coin drop together from the top of the exhausted receiver of an air-pump, they will both be seen to descend at the same rate, and reach the bottom at the same instant; a fact which may be demonstrated more simply by placing the coin and feather free of each other in a paper cone, and letting the cone fall with its apex downwards, so as to break the air's resistance; or by suspending a piece of gold-leaf in a bottle, and letting the bottle drop—of course short of the ground—in which case the included leaf will be seen to have gone as fast and as far as the bottle.

It is to be especially noticed that attraction is no lopsided affair; that it is mutual; that, while the larger body attracts the less, the less also attracts and moves the larger in proportion; and that, indeed, every body and every particle attracts every other, far as well as near, to the utmost verge of the universe of matter. Under it the moon maintains its place with reference to the earth, the planets with reference to the sun, and the solar system with reference to the stellar. As for the moon, it maintains its orbit and revolves round the earth under the action of two forces, the one akin to that by which a ball is projected from the mouth of a cannon, and the other the attraction of the earth, which, by its constant and equal operation, bends its otherwise rectilineal track into a circular one, as we might show if we could only project a ball with such a force as exactly to balance the power of gravity, so that it would at no point in its course be drawn nearer the earth than at starting.

That the force we are considering pervades the solar system is demonstrable, for it is on the supposition of it and the laws it is known to obey that all the calculations of astronomy—and they never miscarry—are grounded; and it is by noticing disturbances in the otherwise regular movements of certain planets that astronomers have been led more than once to infer and discover the presence of some hitherto unknown body in the neighbourhood. It was actually thus the planet Neptune was discovered in 1846. Certain irregularities had been observed in the movements of Uranus, which could not be accounted for by the influence of any other bodies known to be near it; and these irregularities, being carefully watched and studied, gradually led more than one astronomer first to the whereabouts, and then to the vision of the disturbing planet.

Notwithstanding what we said about the universality of this force, and how it affects all forms of matter, it may still appear as if the air were an exception. But it is not so; the air also gravitates. The fact that it gravitates is proved in various ways. First, if it did not, it would not accompany the earth in its movements round the sun; the earth would sweep along into space, and leave it behind it. Secondly, if we place a bottle from which the air is exhausted in a balance and exactly poise it with a counter-weight, and then open it and let in the air, it will show at once that the air has weight or gravitates by immediately descending. Thirdly, if we extend a piece of india-rubber over the end of a vessel and begin to withdraw the air from it, we shall see the india-rubber sink in, under the pressure of the air outside, to fill up the space left vacant by the removal of the included air. The fact that air gravitates we have already taken for granted in explaining the ascent of a balloon; and the proofs now given are enough to show that the cause assumed is a real one. The lighter gas rises and the heavier sinks by law of gravitation.

Gravitation and Cohesion.—Unlike the attraction of aggregation, or cohesion, which acts only between particles separated from each other by spaces that are imperceptible, gravitation takes effect at distances which transcend conception, but it diminishes in force as the distance increases. The law according to which it does so is expressed thus; its intensity decreases with the square of the distance; that is to say, at twice the original distance it is 1-4th; at thrice, 1-9th; at four times, 1-16th, for 4, 9, 16 are the squares respectively of 2, 3, and 4. To take an instance, a ball which weighs 144 lb. at the surface of the earth will weigh 1-4th of that, or 36 lb., when it is twice as far from the centre as it is at the surface; and 1-9th, or 16 lb. when it is thrice as far; and 1-16th, or 9 lb. when it is four times as far. The attraction of cohesion, on the other hand, as we say, acts only when the particles seem almost in contact, and it ceases altogether when once, by mechanical or other means, the bond is broken, in consequence of the particles being forced too near, or sundered too far from, one another.

One distinguishing difference between the attraction of gravitation and that of cohesion is, that whereas the former is uniform, the latter is variable; that is, under gravitation the attraction of any one particle to any other is the same, but under cohesion, some sets of particles are more forcibly drawn together than others. For instance, a particle of iron and a particle of cork gravitate equally, but particles of iron and particles of cork among themselves do not cohere equally. And it is just because those of the former cohere more than those of the latter, that a piece of iron feels harder and weighs heavier than a piece of cork.

Further, the attraction of gravitation is unaffected by change in the condition of bodies, while that of cohesion is. It makes nothing to gravitation whether a piece of metal is as cold as ice, or heated with a sevenfold heat. Not so to the power of cohesion; withdraw heat, and the particles under cohesion cling closer; add it, and both the spaces grow wider and the attraction feebler. Thus, for example, you may suspend a weight by a piece of copper-wire, and the wire not break. But apply heat to the wire, and its cohesion will be lessened; the force of gravitation will overpower it, rupture the wire, and cause the weight to fall.

Cohesion.—That the action of the attraction of cohesion depends on the contiguity of the particles in the cohering body, may be shown by an illustration. Take a ball of lead, divide it into two hemispheres, smooth the surfaces of section, then press them together, and you will find it requires some force to separate them; thus proving the dependence of cohesion on contiguity, although the effect in this case may be due in some degree to the pressure of the atmosphere as well as the power of cohesion.

Heat is the principal agent in inducing cohesion, as well as in relaxing its energy; for by means of it you can weld the hardest as well as the softest substances into one, and two pieces of iron together, no less than two pieces of wax. It is possible, indeed, by heat to unite two sufficient waxed corks to one another, so as to be able by means of the one to draw the other out of a bottle: such, in this case, is the force of cohesion induced by heat.

The power of cohesion exists between the particles of liquids as well as those of solids, the only difference being that in solids the particles are relatively fixed, while in liquids they move freely about one another, unless indeed when they are attracted to the surface of a solid—a fact we are familiar with when we dip our finger into a vessel of water. The cohesive power of liquids is overcome by heat as well as that of solids, only to a much greater degree, for under it they assume a new form, acquire new properties, and expand immensely in volume. They pass into the form of vapour, occupy a thousand times larger area, and possess an elasticity of compressibility and expansibility they were destitute of before.

There is a beautiful phenomenon which accompanies the expansion of ether under the influence of heat. Placed in a flask to which heat is applied, the ether will go off in vapour; and as the heat increases, the vapour will gradually light up into a lovely flame. The expansibility of air, which is vapour in a permanent form, can be shown by experiment. If we tie up an empty or collapsed bladder, and place it in a vessel over an air-pump, we may see, as we withdraw the air from the vessel, and so diminish its pressure, the bladder gradually expand and swell as it does under inflation.

The cohesive power of water is beautifully illustrated. Have a small barrel or bucket so constructed as to be fitted with gauze at the top; immerse it exactly, so that the water may form a film between the meshes, and then open the tap at the bottom: the water will not flow till the meshes at the top are broken by blowing on their surface. The adhesion of the particles in a soap-bubble is another illustration, no less beautiful, as well as more familiar; for the soap, which might be supposed to be the cause of the phenomenon, serves only to prevent the intrusion of dust between the particles, but by no means to intensify their attractive power.

There are some liquids the adhesiveness of whose particles is so perfect as to bar out the access of air when we strew them on the surface of other liquids; and on the Continent it is not uncommon to protect wines against the action of the atmosphere by, instead of corking the bottle, simply pouring in a few drops of oil, which, being lighter than the wine, floats on the surface. It is parallel to the instance of the barrel with the gauze-wire top mentioned above, that if we loosely plug a bottle full of liquid with a piece of cotton-wool, and invert it, the particles in contact with the wool will cohere so closely that the fluid will not be able to escape. The adhesiveness of the particles of water to a solid surface can be exemplified by allowing one of the scales of a balance to float in water and leaving the other free; the one in contact with the water will refuse to yield after we have placed even a tolerable weight in the other which is suspended in the air.

The power of cohesion is more rigorous in some bodies than others. In some cases the body will rupture if it is interfered with ever so little; in others, the particles admit of a certain displacement, and if the limits are not transgressed, they return to their original position when the compressing or distending cause is removed. This rallying power in the cohesive force is called Elasticity, and it exists in no small degree in glass. The spaces between the particles can, within limits, be either lessened by compression or increased by distension, and the particles retain their power of recovering and maintaining the relation they stood in before they were disturbed. It is the power of cohesion or aggregation which resists any disturbance among the particles, and which restores order among them when once disturbance has taken place. And not only does nature resist directly any undue interference with the cohering force, but tampering with it even slightly has often a certain deteriorating effect upon the physical properties of bodies. A bell, for instance, loses its tone when heated, because by that means its particles are disturbed; though it recovers its tone-power as it cools, and as the particles return to their places.

In organic bodies, both during growth and decay, the particles are more or less in flux; but in feathers, after their formation, the attraction of aggregation remains constant, and by means of it their particles continue fixed in their places, not only with the life of the bird, but long after. Nay, you may even crumple them up, and toss them away as worthless, and yet if you expose them to the vapour of steam, they will not only recover their form, but they can be made to look as beautiful as ever.

Chemical Affinity.—The attraction of the particles of bodies of different kinds to each other is often striking and curious; as, for instance, those of salt to those of water. The salt attracts the water, and the water the salt, till at last, if there is a sufficient quantity of water, all the salt is attracted particle by particle from itself, and taken up and united to the water. The salt is no longer visible to the eye, and is said to be dissolved or in solution; but this change of form is due to its affinity for the water, and the resulting attraction of the one to the other. The same phenomena are observed, and they are due to the same cause, in other solutions; as when we infuse our tea or sweeten it with sugar. The attraction of water, or one of its elements rather, for other substances, sometimes shows itself in vehement forms. When a piece of potassium, for example, is thrown into a vessel of water, its attraction for the water is such, and of the water for it, that it instantly takes fire, and the two blaze away, particle violently seizing on particle until the elements of the water unite part for part with the metal. It is the mutually attractive force that causes the heat and flame which accompany the combination; and this force is most violently active in the union of dissimilar substances. Unions of a quieter kind, though not less thorough, occur even between solids when placed in contact. For instance, sulphate of soda and sulphate of ammonia, when placed side by side, will diliquesce, and in liquid form unite into a new combination. Sulphuric acid, when we mix it with water, generates great heat; and this is due to its attraction for the water. Sometimes two fluids unite together, and, in doing so, pass from the liquid into the solid form; as, *e.g.*, sulphuric acid and chloride of calcium. Attraction of this nature is called chemical: it takes effect between dissimilar particles, and results in combinations with new properties. It operates not only between solid and solid, solid and liquid, and liquid and liquid, but between these and gases, and gases with one another; and these as well as those combine into new substances, and evince in the act not a little violent commotion. Thus, phosphorus catches fire in the atmosphere at a temperature of 140 degrees, and it goes on rapidly combining with the oxygen, burning with a dazzling white light, and producing phosphoric acid. Indeed, most metals have an affinity for the oxygen in the air, and oxydise in it with more or less facility; and a metal, as such, has more value than another according as it has less affinity for that element, and is less liable to oxydise or rust in it. This is one reason, among others, why gold is the most precious metal, and the conventional representative of highest worth in things.

There are some metals, such as lead, for instance, which oxydise readily, but this process stops short at the surface in contact with the air, and so forms a coating which prevents the metal from further oxydation; so that here, as in so many things else, strength is connected with weakness.

Electricity.—This, in the most elementary view of it, is a more or less attractive or repellant force latent in bodies, and which is capable of being roused into action by the application of friction. It is excited in a rod of glass by rubbing it with silk, and in a piece of sealing-wax by rubbing it with flannel, though the effect is different when we apply first the one and then the other to the same body. Thus, *e.g.*, if we apply the excited sealing-wax to a paper ring, or a pith-ball, hung by a silk thread from a horizontal glass rod, it will, after contact, repel it; and if, thereafter, we apply to it the excited glass rod, it will attract it; or if we first apply the excited glass rod to the paper ring, or pith-ball, it will, after contact, repel it; and if thereafter we apply to it the excited sealing-wax, it will attract it. The reason is, that when we once charge a body by contact with either kind, it repels that kind, and attracts the opposite; if we charge it from the glass, *i.e.*, with vitreous electricity, it refuses to have more, and is attracted to the sealing-wax; and if we charge it from the sealing-wax, *i.e.*, with resinous electricity, it refuses to have more, and is attracted to the glass-rod; only it is to be observed that, till the body is charged by either, it has an equal attraction for both. From all which it appears that kindred electricities repel, and opposite attract, each other.

Two pieces of gold leaf suspended from a metal rod, inserted at the top of a glass shade full of perfectly pure, dry air, will separate if we rub our foot on the carpet, and touch the top of the rod with one of our fingers; for the motion of the body, as in walking, always excites electricity, and it is this which, as it passes through the finger, causes the phenomenon; though the least sensation of damp in the glass would, by instantly draining off the electricity, defeat the experiment. What happens in this case is, that one kind of electricity passes from the finger to the leaves, while another kind, to make room for it, passes from the leaf to the finger; and the leaves separate because they are both more or less charged with the same kind of electricity, and kindred electricities repel each other. Ribbons, particularly of white silk, when well washed, are similarly susceptible of electrical excitation; and they behave very much as the gold leaf does when they are rubbed sharply through a piece of flannel. Gutta-percha is another substance which, when similarly treated, is similarly affected.

This power is a very mysterious one, and of a nature to perplex even the philosophic observer. Certain bodies, such as the metals, convey it, and are called conductors; certain others, such as glass and porcelain, arrest it, and are called insulators. It is for this reason that the wires of the telegraph are supported by a non-conductor, for if not, the electric current would pass into the earth by the first post and never reach its final destination. Glass being an insulator, it was found that, if a glass bottle was filled with water, and then corked up with a cork, through which a nail was passed so that the top of it touched the water, it would receive and retain a charge as long as it was held in the hand; and this observation led to an invention of some account in the subsequent applications of electricity, known, from the place of its conception, as the Leyden jar. This is a glass jar, the inside of which is coated with tinfoil, and the outside as far as the neck, and into which, so as to touch the inside coating, a brass rod with a knob at the top is inserted through a cork, which closes its mouth. By means of this, in consequence of the isolation of the coatings by the glass, electricity can, in a dry atmosphere, be condensed, and stored up and husbanded till wanted.

A series of eggs, arranged in contact and in line, give occasion to a pretty experiment. In consequence of the shells being non-conductors, and the inside conducting, it happens that a current of electricity, applied to the first of the series, will pass from one to another in a succession of crackling sparks, in this way forcing itself through the obstructing walls. This effect of electricity in making its way through non-conducting obstructions accounts for the explosion which ensues when a current of it comes in contact with a quantity of gunpowder; as it also does for the fatal consequences which result when, on its way from the atmosphere to the earth, it rushes athwart any resisting organic or inorganic body.

Magnetism.—Unlike electricity, which acts with a shock and then expires, magnetism is a constant quantity, and constant in its action; and it has this singular property, that it can impart itself as a permanent force to bodies previously without it. Thus, there being natural magnets and artificial, we can, by passing a piece of steel over a magnet, turn it into a strong magnet itself; although we can also, when it is in the form of a horse-shoe, by a half turn round and then rubbing it on the magnet, take away what it has acquired, and bring it back to its original state. The magnetic property is very readily imparted (by induction, as it is called) to soft iron, but when the iron is removed from the magnetising body, it parts with the virtue as fast as it acquired it. To obtain a substance that will retain the power induced, we must make some other election; and hard steel is most serviceable for conversion into a permanent magnet.

The properties of the magnet are best observed in magnetised steel; and when we proceed to test its magnetic power, it will be found that it is most active at the extremities of the bar, which are hence called its poles, and hardly, if at all, at the centre; that while both poles attract certain substances and repel others, the one always points nearly north and the other nearly south when the bar is horizontally suspended; and that, when we break the bar into two or any number of pieces, however small, each part forms into a complete magnet with its virtue active at the poles, which, when suspended, preserves its original direction; so that of two particles one is, in that case, always north of the other; nay, it is probable that each of these has its north pole and its south, as constant as those of the earth itself, which, too, is a large magnet.

The magnet acts through media and at a distance, as well as in contact; and it has an especial attraction for iron, the more so when the conducting medium is solid, such as a table; and so when the magnet is horizontally suspended, or poised, in the vicinity of iron, its tendency to point north and south is seriously disturbed. The disturbance of the bar, or needle, in such a case, is called its *deflection*; and it is corrected by so placing a piece of soft iron or another magnet in its neighbourhood as to neutralise the effect, and leave said bar, or needle, free to obey the magnetism of the earth. The needle, it is to be remarked, does not point due north and south, neither, when poised freely on its centre, does it lie perfectly horizontal; in our latitude it points at present 20° west of north, which is called its *declination*, and its north pole slopes downwards at an angle of 68°, which is called its *dip*.

By holding a rod of iron, or a poker, for a length of time parallel to the direction of the needle, so as to have the same declination and the same dip, it will gradually assume and display magnetic virtue, and this will ere long become fixed and powerful under a succession of vibratory shocks. There is a beautiful experiment in which a needle, when magnetised, can be made to float on water, when it adjusts itself to the magnetic meridian, and will incline north and south the same as the needle of the compass.

The Chemical Action of Electricity and Magnetism.—These agents possess powers which develop wonderfully in connection with chemical combination. Thus, if we suspend a piece of iron in a vessel which contains oxygen gas, and apply to the metal an electric current, it will immediately begin to unite rapidly, and form an oxide with oxygen, emitting, during the process, intense heat and a bright flame. Zinc, too, when similarly acted on, will ignite in the common atmosphere and burn away, though with less intensity, till it also is, under the electric force, reduced to an oxide. It is presumed that many other chemical combinations take place because of the simultaneous joint development of electric agencies, as in copper, water, and aquafortis, nitrate of copper, &c. So also it happens that, when a plate of iron is for some time immersed in a copper solution, it comes out at length covered over with a coating of copper. And it is because there is electricity at work that a silver basin will be coated with copper when we pour into it a copper solution, and at the same time place in it a rod of zinc, so that it rests on the side and bottom, though no coating will form at all when there is no rod present to excite the electric current. The same phenomena will appear if we deposit a silver coin in the solution in question: the coin will come out unaffected, unless we excite affinity by means of a rod of iron. It is under the action of an electric current that one metal is coated with another. The metal, copper say, is steeped in a solution of the coating substance, and connected by means of wires with a galvanic battery, under the action of which the metal in solution unites with the surface of the plate immersed in it. Heat also is developed under magnetic influence, and that often of great intensity. Thus, if we connect the poles of a voltaic battery by means of a platinum wire, heat will develop to such a degree that the platinum will almost instantaneously become red hot and emit a bright light, and that along a wire of some considerable length. A similar effect is noticeable when we substitute other metals, such as silver or iron, for platinum. And the *electric light*, which flashes out rays of sunlike brilliance, is the result of placing a piece of compact charcoal between the separated but confronting poles of a powerful galvanic battery, light, developing more at the one pole and heat more at the other of the incandescent substance.

Kindred, though much milder, results will show themselves under simpler, though similar, contrivances. A flounder will jump and jerk about uneasily if we lay it upon a piece of tinfoil and place over it a thin plate of zinc, and then connect the two with a bent metal rod; which will happen to an eel also, if we expose it to a gentle current from a battery.

By means of electric or magnetic action we can separate bodies chemically combined, as well as unite them into chemical compounds; as will appear if we place a piece of blotting paper upon tinfoil, and this upon wool; if we then spread above these two pieces of test-paper, litmus and turmeric, the one the test of acids, and the other of alkalis, and saturate both with Glauber salt (which is by itself neither an acid nor an alkali, but a combination of the two), and, finally, connect each by means of a piece of zinc with the poles of a battery, the test-papers will immediately change colour, as they do the one in the presence of an acid simply, and the other of an alkali simply, but never in a compound where these are neutralised; thus proving that the compound has in this case been decomposed, and its elements disintegrated one from another.

A very powerful magnet can be produced by coiling a wire round a bar of soft iron, and attaching its extremities to the poles of a galvanic battery, when it will be found that its strength will be proportioned to the strength of the current and the turns of the coil. This is especially the case when the bar is bent into the form of a horse-shoe, and the wires are insulated and coiled round its limbs. The force communicated to a magnet of this kind, which is often immense, is the product of the chemical action which goes on in the battery, and, in a certain sense, the measure of it. How great that is we may judge when we consider that, evanescent as it is in itself, it has imparted a virtue which is both powerful and constant, and ever at our service.

Summary.—Thus, then, on a review of the whole, we find all things are endowed with attractive power, and that there is no particle which is not directly or indirectly related, in manifold ways, to the other particles of the universe. There is, first, the universal attraction of gravitation, under which every particle is, by a fixed law, drawn to every other within the sphere of existence. There is, secondly, the attraction of cohesion or aggregation, which acts at short distances, and unites the otherwise loose atoms of bodies into coherent masses. There is, thirdly, the power by which elements of different kinds combine into compounds with new and useful qualities, known by the name of chemical affinity. And, lastly, related to the action of affinity, aiding in it and resulting from it, there are those strange negative and positive, attractive and repellant polar forces which appear in the phenomena of electricity and magnetism, agencies of such potency and universal avail in modern civilisation.

On the permanency of such forces and their mutual play the universe rests, and its wonderful history. With the collapse of any of them it would cease to have any more a footing in space, and all its elements would rush into instant confusion. What a Hand, therefore, that must be which holds them up, and what a Wisdom which guides their movements! Verily, He that sends them forth and bids them work His will is greater than any one—greater than all of them together. How insignificant, then, should we seem before Him who rules them on the wide scale by commanding them, while we can only rule them on the small by obeying them! And yet how benignant must we regard Him to be who both wields them Himself for our benefit and subjects them to our intelligence and control!

FOOTNOTES:

[B] This paper on "Attraction" is the substance of a lecture which I composed on the basis of notes taken by me when. I had the honour of attending the Prince of Wales at the course given, on the same subject by the late Professor Faraday. The Professor, having seen the *resumé* I had written, warmly commended the execution, and generously accorded me his sanction to make any use of it, whether for the purpose of a lecture or otherwise, as might seem good to me. It is on the ground of this sanction I feel warranted to print it here.

THE OIL FROM LINSEED.

Various processes have for a long time been in use for the purpose of extracting the oils from different species of nuts and seeds, a few of the more interesting of which are not unworthy of brief notice and description.

In Ceylon, where cocoa-nuts and oil-producing seeds abound, the means employed by the natives in the last century for extracting the oils were of a most primitive character. A few poles were fixed upright in the ground, two horizontal bars attached to them, between which a bag containing the pulp of the seed or nut was placed. A lever was then applied to the horizontal bars, which brought them together, thus creating a pressure which, by squeezing the bag, gradually expressed the oil from the pulpy substance. This rude machine was at that time of day one of the most approved for the purpose.

The system of pestle and mortar was also in use, but as the process was necessarily very slow, this method was seldom resorted to. An improvement on this system was invented by a Mr. Herbert, whose design it had been to construct a powerful and efficient machine which should combine cheapness and simplicity. It consisted of three pieces of wood, viz., an upright piece fixed in the ground, from the lower and upper extremities of which there projected the two other pieces, the top one attached to the joint of a long horizontal lever, and the lower one to the joint of a vertical one. The fixed upright post and the horizontal lever formed the press. The bag of pulp being put between the upright one and the vertical, the pressure was obtained by suspending a negro or a weight from the lever.

In another press of the same or a similar kind, the bags were placed in a horizontal frame, and a loose beam of wood pressed down on it by a lever.

Another form of press had cambs and wedges; also a modification of it by Mr. Hall of Dartford, who applied the pressure by means of a steam-cylinder. The cambs are arranged alternately, so that one is filled while the other is being pressed. This brief notice will suffice to give an idea of such machines as are wrought by lever pressure.

We pass on, therefore, to later inventions and improvements.

First, The Dutch or *stamper* press, invented in Holland; second, the *screw*; and, third, the *hydraulic*:—

(1.) *The stamper press* is something like a beetling-machine, in which wedges are driven in between the bags, containing, of course in a bruised condition, the seed to be pressed.

(2.) *The screw press* has an ordinary square-threaded screw, and it acts in the same way as press for making cider or cheese.

(3.) *The hydraulic press*. Here the pressure is produced by means of a piston driven up by the force of water, the immense power of which is, in great part, due to its almost total incompressibility. This is by far the most perfect form of press. Its power must be familiar to all who remember the lifting of the tubes of the Britannia Bridge, and the *launching of the Great Eastern*.

An oil-mill is in form something like a flour-mill. The operation begins at the top, where the seed is passed through a flat screw or shaker and then through a pair of rollers, which crush it. These rollers are of unequal diameter, the one being 4 feet, and the other 1 foot; but they are both of the same length, 1 foot 4 inches, and make fifty-six revolutions in a minute. By this arrangement it is found the seed is both better bruised and faster than when, as was formerly the case, the rollers were of the same diameter. A pair of rollers will crush 4-1/2 tons of seed in eleven hours, a quantity enough to keep two sets of hydraulic presses going.

After the seed is crushed in this way, it is passed under a pair of edge stones. These stones weigh about seven tons, are 7 feet 6 inches in diameter and 17 inches broad, and make seventeen revolutions a minute. If of good quality, they will not require to be faced more than once in three years, and they will last from fifteen to twenty. They are fitted with two scrapers, one for raking the seed between the stones, the other for raking it off at the proper period. One pair of stones will grind seed sufficient for two double hydraulic presses, and the operation occupies about twenty-five minutes. The seed is now crushed and ground, but before it is passed on to the press it is transferred to the heating-kettle.

The heating-kettle is composed of two cylindrical castings, one fitting loosely into the other, so that a space is left between them for a free circulation of steam all round both the sides and bottom of the interior vessel. The internal casting is again divided horizontally into two partitions, one above the other therefore, by two plates, between which also there is a space left for the admission and circulation of steam; and a communication is kept up between the upper compartment and the under by means of a stripping valve. Besides this, there is a communication from the internal kettle through the external one, and also a shaft passes between the two horizontal parts to give motion to the stirrer, which revolves thirty-six times a minute. A cover encloses the top, and it is through this the vessel is charged. The upper portion is filled first, where the contents introduced are allowed to remain ten or fifteen minutes, after which the valve is opened and the whole falls into the lower kettle, where it is kept till wanted. The seed is then taken away from the lower kettle by an opening, and bestowed in bags of sufficient size to make a cake of 8 lbs. weight after the oil is pressed out of it. Indeed, the compartments of the heating-kettle are of a size to contain enough to charge one side of a hydraulic press. These, therefore, are so constructed as to render the operation continuous, the upper one being discharged into the under as soon as its contents are withdrawn to the press. The seed is heated to the temperature of 170 degrees Fahr., when it is drawn off and placed in the bags.

In another form of kettle the seed is heated on a hot hearth, and on the top of the hearth is a loose ring, within which a spindle revolves to stir the seed. After the requisite temperature has been reached, the ring is raised and the seed swept into the bags, which are made of horse-hair. There is great loss of heat in this method, however, as the seed is exposed to the atmosphere, which of course cools it.

We now come to the final operation, the mode of expressing the oil. The screw press we do not need to describe, as it consists simply of two plates, brought together by a screw, in the same way as the press used for squeezing apples in the manufacture of cider, and the cheese press. Let us look therefore at the stamper press. It consists of an iron box, open at the top, at each end of which are two plates, capable of containing between them a bag of seed which shall yield a cake weighing 9 lbs. To one of the inner plates of the box is attached a wedge, beside which is inserted another filling up, and then the driving wedge is introduced; and lastly, another block is let in between this wedge and the other plate as soon as the bags have been placed vertically in the press-box. A stamper of wood, worked by cambs on a revolving shaft, is allowed to fall about 1 foot 10 inches, at the rate of fifteen strokes a minute, for about six minutes. This stamper is 16 feet long by 8 inches square, and falls on the head of the wedge, and drives it in to a level at the top of the box. Another stamper is employed to drive down an inverted wedge, so as to release the working one, and enable the attendant to take out the cake. A press of this kind will turn out only about 12 cwts. of cake a day.

We come now to the hydraulic press. This is certainly the most approved invention that has yet been adopted, and it is simply a Bramah press adjusted for the purpose. It has been in use for about thirty years, though it was, of course, at first less skilfully and scientifically constructed than it is now. In one of the earliest of these presses, the box which contains the seed runs on a tramway in order to facilitate its removal from the heating-kettle, so that each time the bags have to be replenished the whole box has to be removed; and this causes no inconsiderable loss both of power and time, for it has, when filled, to be replaced on the ram and lifted bodily upwards in order to bring it flush with the top of the press, which fits the press-box and acts as a point of resistance. In this arrangement there are introduced only one press and one set of small pumps.

The next press we come to is Blundell's, which is admitted to be by far the most efficient in use to-day. Here there are two distinct presses, or a double hydraulic press, fed by two pumps, one 2-1/2 inches and the other 1 inch in diameter, both connected with the separate cylinders by hydraulic tubing. The stroke of these pumps is 5 inches, and they make thirty-six strokes a minute. The larger pump is weighted to 740 lbs. on the square inch, and the smaller to 5540 the square inch. The diameter of the rams is 12 inches, and the stroke 10 inches. Each press is fitted to receive four bags of seed, and it produces 64 lbs. of cake at each operation. After the heated seed has been placed in the bags, the attendant proceeds to fill one press, and then he opens the valve between the large pump and the charged press, which causes the ram to rise till there is a pressure of forty tons, whereupon the safety-valve of the large pump opens, and is kept so by a spring. While this operation is going on, the attendant is occupied with filling the second press; which completed, he opens the communication between the large pump and the second press, taking care first to replace the safety-valve. The ram of this press is then raised to the same height as the other, after which the safety-valve rises a second time. The attendant, as he closes the valve which opens the communication between the large pump and the press, at the same time opens the valve between the small pumps and the presses; and the pressure, amounting to about 300 tons, exerted by the small pump, is allowed to remain on the rams for about seven minutes. From which it appears that, allowing three minutes for emptying and charging the press, the process of expressing the oil takes only three minutes in all; and it is done by this press in this brief time in the most effectual manner. The oil, as it is expressed, passes through the canvas and hair bags to a cistern, known as the spill-tank, which is just large enough to contain the produce of one day's working. The presses are worked by oil instead of water, as it keeps both presses and pumps in better order. Each of them will produce 36 cwts. of cake per day of eleven hours, while the yield of oil is about 14 cwts. The oil is pumped from the spill-tanks to larger ones, capable of holding from 25 to 100 tons, where it remains for some time in order to settle previously to being brought to the market.

I do not intend to enter into the relative merits of the various presses, but content myself with having explained to you the manner in which the oil is produced.

Before concluding, it may be interesting to give you some idea of the vast extent of this manufacture. It appears, according to the official returns, that in the year 1841 we imported 364,000 quarters of seed.

THE OIL FROM LINSEED.

1842	368,000	1847	439,000	1852	800,000
1843	470,000	1848	799,000	1853	1,000,000
1844	616,000	1849	626,000	1854	828,000
1845	666,000	1850	668,000	1855	757,000
1846	506,000	1851	630,000	1856	1,100,000

Now if we take the last year's imports, we shall find that the produce would amount to about 144,000 tons' weight of oil-cake, and above 56,000 tons of oil.

The cake is used for feeding cattle, and the oil for burning, lubricating, painting, &c.; and a very large quantity is exported.

We find that to crush the seed imported in 1856 it required from 150 to 160 double hydraulic presses, nearly 100 of which were in Hull. This shows the extent of our commerce in the seed of flax, to say nothing of its fibre; and is one more instance of the great results which may be wrought out of little things. What a beautiful illustration of the bounty of Providence; and what an encouragement to the ingenuity of man! Who knows what treasures may yet lie hidden in neglected fields, or to what untold wealth the human family may one day fall heir?

HODGE-PODGE: OR, WHAT'S INTILT.

WRITTEN NOV. 20, 1875, AT STAGENHOE PARK.

The subject and treatment, as well as title, of this Lecture are suggested by the answer of the hostess at a Scottish inn to an English tourist, who was inquisitive to know the composition of a dish which she offered him, and which she called Hodge-Podge. "There's water intilt," she said, "there's mutton intilt, there's pease intilt, there's leeks intilt, there's neeps intilt, and sometimes somethings else intilt." The analysis was an exhaustive one, and the intelligence displayed by the landlady was every way worthy of the shrewdness indigenous to her country; but her answer was not so lucid to her listener as to herself, as appeared by his bewildered looks, and his further half-despairing interrogatory. "But what is *intilt*?" said he, impatiently striking in before she had well finished. "Haven't I been tellin' ye what's intilt?" she replied. And she began the enumeration again, only with longer pause and greater emphasis at every step, as if she were enlightening a slow apprehension,—"There's water intilt, there's mutton intilt;" quietly and self-complacently adding, as she finished, "Ye surely ken now what's intilt." Whether her guest now understood her meaning, or whether he had to succumb, contented with his ignorance, we are not informed; but few of my readers need to be told that "intilt" is a Scotch provincialism for "into it," and that the landlady meant by using it to signify that the particulars enumerated entered as constituents *into* her mysterious dish.

My aim is to discourse on the same constituents as they display their virtues and play their parts on a larger scale, in a wider economy; and when I have said my say, I hope I may be able to lay claim to the credit of having spoken intelligibly and profitably, though I must at the outset bespeak indulgence by promise of nothing more than the serving up of a dish of simple hodge-podge. The question I put in a wider reference is the question of the Englishman, as expressed in the Scotchwoman's dialect, What's intilt? and I assume that there enter into it, as radically component parts, at least the ingredients of this motley soup. Into the large hodge-podge of nature and terrestrial economics, as into this small section of Scotch cookery, there enter the element of water, the flesh of animals, and the fruits of the earth, as well as the processes by which these are brought to hand and rendered serviceable to life. The ingredients of hodge-podge exist in *rerum natura*, and the place they occupy and the function they fulfil in it are no less deserving of our inquisitive regard.

Thus, there is water in it, without which there were no seas and no sailing of ships, no rivers and no plying of mills, no vapour and no power of steam, no manufacture and no trade, and not only no motion, but no growth and no life. There is mutton, or beef, in it, and connected therewith the breeding and rearing of cattle, the production of wool, tallow, and leather, and the related manufactures and crafts. There are turnips and carrots in it, the latter of such value to the farmer that on one occasion a single crop of them sufficed to clear off a rent; and the former of such consequence in the fattening of stock and the provision of animal food, that a living economist divides society exhaustively into turnip-producing classes and turnip-consuming. There are leeks and onions in it, and these, with the former, suggest the art of the gardener, and the wonderful processes by which harsh and fibrous products can be turned into pulpy and edible fruits. And there are pease and barley in it, and associated therewith the whole art of the husbandman in the tillage of the soil and the raising of cereals, with the related processes of grinding the meal, baking the bread, preparing the malt, brewing the beer, and distilling the fiery life-blood at the heart.

Now, to discourse on all these, as they deserve, would be a task of no ordinary magnitude, but the subject is an interesting one, and to treat of it ever so cursorily might not unprofitably occupy a reflective moment or two. Water is the first topic it is laid upon me to talk about, and I begin with it all the more readily because it suggests a sense of freshness, and thoughts which may float our enterprise prosperously into port.

I. Water, as already hinted, is an element of vast account in the economy of nature, and is a recreation to the heart and a delight to the eye of both man and beast. To have a plentiful supply of it is one of the greatest blessings of God to the creature, and to be able to bestow it wisely and employ it usefully is one of the most serviceable of human arts. It is too valuable a servant to suffer to go idle, and many are the offices it might do us, if, as it travels from the mountains to the sea-board, we caught it in its course, harnessed it to our chariot, and guided it to our aim. We should turn it to account every inch of its progress, and compel it, as it can, to minister to our requirements by its irresistible energy. Its merely mechanical power is immense, and this is due in great part to its incompressibility; for it is in virtue of this quality alone we can, by means of it, achieve feats not otherwise feasible. How else could we have raised to its sublime height that stupendous bridge which spans the Menai Straits, and which is the wonder of the beholder, as it is the boast of the designer? It stands where it does by the help of some mechanism indeed, but the true giant that lifted it on his shoulders and bore it to its airy elevation was the incompressible force of water, a fluid which is, strangely, the simple product of the combination of two elastic transparent gases, oxygen and hydrogen, neither of which apart has the thew and sinew of its offspring. Nay, it is this single element, which, acted on by heat or acting through machinery, fetches and carries for us over the wide globe, and is fast weaving into one living web the far-scattered interests of the world.

Water was in primitive times utilised into a motive power by the help of a mechanism of rude design, which yet is hardly out of date, and might recently be seen in its original, still more in modified form, in certain back-quarters of civilisation. A stream, guided by a sluice, was made to play upon four vertical paddle-blades, attached to a shaft which they caused to revolve, and which moved a millstone, resting upon another through which it passed. It was a primitive mill, which superseded the still more primitive hand-mill, or quern; and I myself have seen it at work in the Shetland Islands, and even the north of Scotland, though it is now done away with even there, still more farther south, and its place supplied and its work done by overshot and under-shot wheel-gear, and improved machinery attached, of less or more complexity. One of the most recent improvements is the Turbine, a sort of Barker's mill; it is of great power, small compass, and acts under a good fall with a minimum expenditure of water-power.

Passing from the consideration of water as a motive power in its natural state, I ask you to notice briefly the gigantic force it can be made to develop under the action of heat. In its normal form the power of water is due, as I have said, to its incompressibility; in the state of vapour, to which it is reduced by heat, its power is due to the counter force of expansion. It was when confined as a state prisoner in the Tower of London that the Marquis of Worcester began to speculate on the possibilities of steam, though he little dreamed of its more important applications, and the incalculable services it might be made to render to the cause of humanity. Suddenly, one day, his musings in his solitude were interrupted by the rattling of the lid of a kettle, which was boiling away on the fire beside him, when, being of a philosophic vein, he commenced to inquire after the cause; and he soon reasoned himself into the conclusion that the motive power lay in the tension of the vapour, and that the maintenance of this must be due to successive additions of heat. The thought was a seed sown in a fit soil, for it led to experiments which confirmed the supposition, and inaugurated others that have borne fruit, as we see. It was a great moment in the annals of discovery, and from that time to this the genius of improvement has moved onward with unprecedented strides; and this in the application of steam-power as well as the results, stupendous as these last have been. For as there is no department of industry that has not made immense advances since, none on which steam has not directly or indirectly been brought to bear with effect; so there has been no end to the ingenuity and ingenious devices by which steam has been coaxed into subjection to human use and made the pliant minister of the master, man. All these results follow as a natural consequence from the first discovery of its motive power by the Marquis of Worcester, and the subsequent invention of James Watt, by which the force detected was rendered uniform, instead of fitful and spasmodic, as it had been before. And yet, important as was the discovery of the one, and ingenious as is the invention of the other, both are of slight account in the presence of the great fact of nature observed by the English nobleman and humoured by the Scottish artisan. The *genie* whom the one captured and the other tamed, is the great magic worker, apart from whose subtle strength their ingenuity had been wasted, and had come to naught.

But here I must restrain my rovings, and recall my purpose to descant on other points. And indeed the uses of water are so numerous and varied that the subject might well engross a lecture by itself; and I must needs therefore cut the matter short. It is only Hodge-Podge, moreover, I have undertaken to dish up before you, and I must keep my word. For, fain as I am to dilate on the many economic virtues of water, I must not forget that the pot contains other ingredients, and that the dish I am serving out of it would yield but poor fare, if it did not.

2. I come therefore to the next ingredient in the soup I am providing; for, as the housewife said, "there's mutton intilt," and it is the most important ingredient in the mess. But the animal which produces it, like the kindred animals that produce the like, serves other purposes as well, and these no less essential to the exigency of the race; and it is of them I propose to speak. It is beside my design to enter on the domain of the sheep-breeder, and attempt an account of the different kinds reared by the farmer; enough to say that, numerous as these are, they are all fed and tended for the benefit of the human family, and that they minister to the supply of the same human wants.

The child, as it frolics on the lawn, stops his gambols and steps gently aside to coax, to caress his woolly-fleeced companion; and the mother talks softly to her child of the innocent darlings, and asks if they are not lovely creatures, and beautiful to look at, as they timidly wander from spot to spot, and nibble the delicate pasture. So it is to the lively fancy of childhood, and so it is to the mother whose affections are naturally melted into softness in the presence of simplicity; but when economic considerations arise, and the question is one of service and value, all such sentimental and aesthetic emotions pass out of court, and only calculations of base utilitarianism fill the eye from horizon to horizon. No doubt the creatures are lovely and beautiful to behold on the meadows and hill-sides of the landscape, which they enliven and adorn; but man must live as well as admire, and unless by sacrifice of the sheep he must not only go without hodge-podge to his dinner, but dispense with much else equally necessary to his life and welfare. The cook requires the sacrifice, that he may purvey for the tables of both gentle and semple; the tallow-dealer requires the sacrifice, that he may provide light for our homesteads, and oil for our engines, both stationary and locomotive; and the wool-merchant and the currier insist on stripping the victim of his fleece, and even flaying his skin, before they can assure us of fit clothing and covering against cold and rain for our bodies and our belongings. And what a wretched plight we should be in, if the sheep, or their like, did not come to the rescue, or the help they are fitted to render were not laid under contribution! For not only might we be fated to go often dinnerless to bed, and to live all our days in a body imperfectly nourished, but our evenings would in many cases be spent without light, and our journeys undertaken without comfort, and our outer man left to battle at odds, unshod and unprotected, with the discomforts of the highway and the inclemency of the seasons. Of all the services rendered by the sheep to the race of man, perhaps the most invaluable is that which is accorded in the gift of wool; and it is for the sake of this alone that, in many quarters, whole flocks, and even breeds, are reared and tended,—so great is the demand for it, and such the esteem in which it is held for the purpose of clothing the body and keeping it in warmth.

3. But, again, to advance a step further, there are, as the landlady of the inn remarked, "neeps intilt." On this part of the subject, that I may pass to the next topic on which I mean to speak, and which is of wider range, I intend to say little. I have already referred to the important place

assigned to this vegetable by a living economist as affording a basis for grouping society into two great classes. To the farmer it is of equal, and far more practical, importance; for it is, by the manner of its cultivation, a great means of clearing the land of weeds; it is the chief support of sheep and cattle through the months of winter; and it is one of the most valuable crops raised on British soil, and of equal account in the agriculture of both England and Scotland. The culture of turnips on farms involves considerable expense indeed, and is sometimes attended with loss, and even failure; but they are of inestimable value in cattle husbandry, as without them our sheepfarms would soon be depopulated, and the animals hardly outlive a winter. One function they, and the like, fulfil in nature, is turning inorganic matter into vegetable, that the component elements may in this form be more readily assimilated into animal flesh and blood; while their introduction as an article of farming is of great importance as rendering possible and feasible a regular rotation of crops.

4. But I must, as I said, hasten on to another ingredient of the dish we are compounding; I refer to barley, for that too, as our gracious hostess would say, is "*intilt*." From this single grain what virtues have been developed! what mildness, what soothing, what nourishment, and what strength! What a source it is to us of comfort, of enjoyment, and of wealth! There is barley-water, for instance, a beverage most harmless, yet most soothing; meet drink for the sick-room, and specially promotive of the secretions in patients whose disease is inflammatory, and who suffer from thirst. Then there is barley-bread, extensively used in both England and Scotland, than which there is none more wholesome to the blood and more nourishing to the system; the meal of which is of service too in the shape of a medical appliance, and, when so used, acts with most beneficial effect. But its strength is not so pronounced or decisive either in the form of an infusion or in that of bread, much as in these forms it contributes to health and vigour: it is not when it is put into the pot, or when bruised by the miller, that it comes out in the fulness of its might; it is when it is immersed in water, and subjected to heat, and metamorphosed into malt. In this form it can be converted into a beverage that is simple and healthful, and, when used aright, conducive to strength of muscle and general vigour of life; but when it has undergone a further process, which I am about to describe, it evolves a spirit so masterful that the weak would do well to withstand its seductiveness, for only a strong head and a stout will dare with impunity to enter the lists with it, and can hope to retire from the contest with the strength unshorn and a firm footstep.[C]

Whisky, which is what I now refer to as the highest outcome of the strength of barley, is, like hodge-podge, of Scotch incubation, and deserves, for country's sake and the fame it has, some brief regard. The process by which the grain is prepared may be described as follows. The grain is first damped, then spread out on a floor, and finally a certain quantity of water and heat applied, when it begins to germinate, which it continues to do to a certain stage, beyond which it is not allowed to pass. At this moment a Government official presents himself, and exacts a duty of the manufacturer for the production of the malt, the authorities shrewdly judging that they are entitled to levy off so valuable an article a modicum of tax. The grain thus prepared is now in a state for further manufacture, and it passes into the hands of the brewer or distiller, to be converted into a more or less alcoholic drink.

First the brewer produces therefrom those excellent beverages called beer and porter, and so contributes to our refreshment, enjoyment, and strength. These beverages are, in one shape or other, nearly in universal demand, and the money spent upon the consumption of Bass and XX almost passes belief. They are exported into every zone of the world, and consumed by every class. And then the distiller takes the grain in the same form, and, by slow evaporation and subsequent condensation, extracts the pure, subtle, and potent spirit we have referred to, and which, in more or less diluted form, we call whisky, or Scotch drink. And this article also, in spite of cautions, is in large demand and extensively exported, though perhaps not so much is consumed among us as was fifty years ago. It is not by any means so bad an article as it has a bad name; for when of good quality, and moderately indulged in, it is perfectly wholesome; only when the quality is bad, or the indulgence excessive, do evil results follow. And indeed such are its merits when good, that it is said dealers sometimes export it to France and other parts, from which it is imported again to this country, transfused into splendidly labelled brandy bottles, and sold untransformed as best brandy!

Little do we think, when eating our quiet dinner at a Scottish country inn, what power and wealth are represented in the hodge-podge which belike forms one of the dishes, and which, by suggestion and in the style of the housewife, we are now analysing. As we disintegrate the mess, and resolve it into its elements, we may well bethink ourselves of the cost of our board on the planet, and of the value of the articles we are daily consuming. To help you to a clearer idea of this, in regard to the article barley alone in the form of malt, let me commend to your attention the following statistical statement:—

A Parliamentary return of 1876 shows that the quantity of *malt* charged with *duty* during the year was—

	BUSHELS.	DUTY.
England,	54,655,274	£7,412,621
Scotland,	2,927,763	396,241
Ireland,	3,346,606	453,883
	————	————
Total of United Kingdom,	60,929,633	£8,262,746

The quantity of barley imported into the United Kingdom during the year was equivalent to 2,736,425 quarters. See how great a fire a little spark, hodge-podge, kindleth!

So much for the quantity of malt produced, and the revenue derived from it, in a year in the United Kingdom. I have spoken of this malt as being convertible into a form which possesses, among other virtues, the power of quenching our thirst. I wish it did not also quench our thirst for the knowledge we all ought to have of its production and really serviceable qualities; that it would stimulate inquiry after such things, and not smother it, as it is too apt to do; and, in general, prompt us to a wiser study of our social wants, and the means at our command for further social improvement; which we might prosecute with less and less recourse to the stimulant virtues of malt in such forms as whisky. And this we may do, if we limit our indulgence in it to the less potent form of it in beer, which, while it is calculated to quench man's bodily thirst, is equally calculated to quicken his mental. How much it contributes to allay the former, and how many thirsty souls are refreshed by it, we may estimate from the statistics of the sale of it furnished by a single firm in London. I refer to the firm of the Messrs. Foster, Brook Street, who are friends of my own, and to whom I should be glad to refer all who may be in want of a wholesome beer, for theirs is so good and genuine. The Messrs. Foster are among the most extensive bottlers and exporters in the country; and I find from the information they have kindly supplied me, that the beer bottled by them for export purposes during the year 1874 was 6000 butts, of 108 gallons each; that their contracts for the supply of bottles during that period represented 25,000 gross, or 5,040,000 bottles, which, if laid end to end, would extend to about 1000 miles; and that their accounts with Bass & Co. alone for that term amounted to £150,000. All, from the highest to the lowest, drink beer in England; and when unadulterated and taken in moderation, it is one of the most healthful beverages of which the human being, man or woman, can partake.

Though I have only partially gone over the ground contemplated at first, I feel I must now draw to a conclusion, which I am the less indisposed to do, as I think in what I have said I have pretty fairly set before you the wonderful properties latent in a basin of hodge-podge. For it is a habit of mine, which I have sought to indulge on the present occasion, to analyse every subject to which my attention is directed, and in which I feel interest, before I can make up my mind as to the proper significance and importance of the whole compound. Thus, for instance, set a dish of hodge-podge before me; it does not satisfy me to be told that it is only a basin of broth, and that it is wholesome fare; I must, as I have now been doing in a way, resolve the compound into its elements, see these in other and wider relations, and refer them mentally to their rank and standing in the larger world of the economy of nature and of social existence. I am always asking "What's intilt?" and am never satisfied, any more than the English tourist, with a bare enumeration: I must subject the factors included to rational inspection, and watch their play and weigh their worth in connection with interests more general.

And if, in the delivery of this lecture, I have persuaded any one to regard common things in a similar light and from a similar interest, I shall deem the time spent on it not altogether thrown away. Mind, not water, is the ultimate solvent in nature, and everything, when thrown into it, will be found in the end to resolve itself into it, or what in nature is of kin to it. And if a Latin poet could justify his interest in man by a reference to his own humanity, so may we rest content with nature when we find that we and it are parts of each other. It is well to learn to look on nothing as private, but on everything as a part of a great whole, of which we ourselves are units; so shall we feel everywhere at home, and a sense of kinship with the remote as well as near within the round of existence.

FOOTNOTES:

[C] The Highlanders are said to be able to offer it a stout defiance, for they can stand an immense quantity; and I have heard of an innkeeper in the north, who, when remonstrated with on account of his excessive drinking, so far admitted the justice of the charge implied, but pled that he could not be accused of undue indulgence the night before, as, whatever he might have drunk during the day, he had, after supper, had only seventeen glasses!

THE END.

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