1801 1825

THE WONDERFUL CENTURY.

A. R. WALLACE

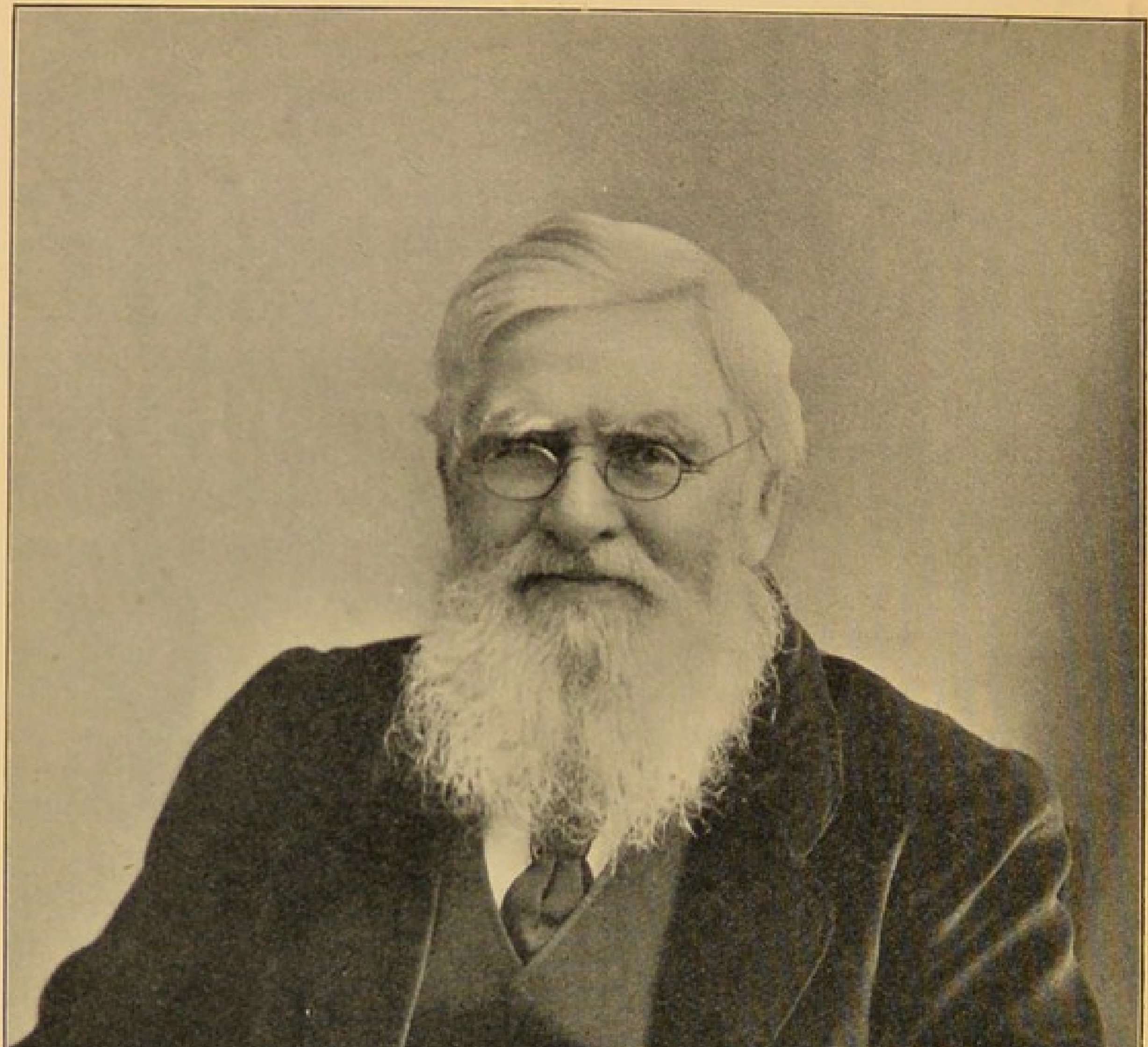
1850

1870 1890

1900

R. H. Elliott

THE WONDERFUL CENTURY



Alfred R. Wallace

THE . . . . . . WONDERFUL CENTURY . . .

THE AGE OF NEW IDEAS IN SCIENCE AND INVENTION

NEW EDITION
Revised and largely Re-written

BY

ALFRED RUSSEL WALLACE

Author of
"The Malay Archipelago," "Island Life," "Darwinism," etc. etc.

WITH 107 *ILLUSTRATIONS*

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PREFACE

The present edition is, substantially, a new work. The earlier editions were very imperfect as regards the small space devoted to several of the more important sciences, as well as to some of the greatest mechanical advances of the century. The chapters on Locomotion by Land and by Sea have now been greatly extended and copiously illustrated. In Photography, I have added a new feature in a popular account of the methods by which artistic illustrations are produced, from the common process-plate to the beautiful photogravures and Woodbury-type prints. The chapter on Chemistry has been greatly extended, and a new one on Electricity has been added. Four new chapters have been devoted to Astronomy, the most ancient of the sciences, and at the same time that which has made the most amazing advance during the nineteenth century. The remaining chapters have been carefully revised and have often received important additions.

To make room for so much new matter in a single volume, the very long chapter on the Vaccination question in former editions has been omitted. It has fulfilled the purpose for which it was originally included in the

work, and this purpose is now better served by its continued issue in a pamphlet form. I may state here that during the five years it has been before the public it has never been replied to, nor have any of the facts or the arguments demonstrating the uselessness of Vaccination been proved to be erroneous.

ALFRED R. WALLACE.

BROADSTONE, DORSET,
30*th June* 1903.

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Part I—Successes

CHAPTER I

MODES OF TRAVELLING

"Put forth your force, my iron horse, with limbs that never tire!
The best of oil shall feed your joints, and the best of coal your fire;
Like a train of ghosts, the telegraph posts go wildly trooping by,
While one by one the milestones run, and off behind us fly!
Dash along, crash along, sixty miles an hour!
Right through old England flee!
For I am bound to see my love,
Far away in the North Countrie."
PROF. RANKINE.

WE men of the nineteenth century have not been slow to praise it. The wise and the foolish, the learned and the unlearned, the poet and the pressman, the rich and the poor, alike swell the chorus of admiration for the marvellous inventions and discoveries of our own age, and especially for those innumerable applications of science which now form part of our daily life, and which remind us every hour of our immense superiority over our com paratively ignorant forefathers.

But though in this respect (and in many others) we undoubtedly think very well of ourselves, yet, in the opinion of the present writer, our self-admiration does not rest upon an adequate appreciation of the facts. No one, so far as I am aware, has yet pointed out the altogether exceptional character of our advance in science and the arts during the century which has just passed away. In order to estimate its full importance and grandeur—more especially as regards man's increased power over nature and the application of that power to

the needs of his life to-day, with unlimited possibilities in the future—we must compare it, not with any preceding century, or even with the last millennium, but with the whole historical period—perhaps even with the whole period that has elapsed since the Stone Age.

Looking back through the long dark vista of human history, the one step in material progress that seems to be really comparable in importance with several of the steps we have just made, was, when Fire was first utilised, and became the servant and the friend instead of being the master and the enemy of man. From that far-distant epoch even down to our day, fire, in various forms and in ever-widening spheres of action, has not only ministered to the necessities and the enjoyments of man, but has been the greatest, the essential factor, in that continuous increase of his power over nature, which has undoubtedly been a chief means of the development of his intellect and a necessary condition of what we term civilisation. Without fire there would have been neither a bronze nor an Iron Age, and without these there could have been no effective tools or weapons, with all the long succession of mechanical discoveries and refinements that depended upon them. Without fire, there could be no rudiment even of chemistry, and all that has arisen out of it. Without fire much of the earth's surface would be uninhabitable by man, and much of what is now wholesome food would be useless to him. Without fire he must always have remained ignorant of the larger part of the world of matter and of its mysterious forces. He might have lived in the warmer parts of the earth in a savage or even in a partially civilised condition, but he could never have risen to the full dignity of intellectual man, the interpreter and master of the laws and forces of nature.

Having thus briefly indicated our standpoint, let us

proceed to sketch in outline those great advances in science and the arts which are the glory of our age. In the course of our survey we shall find, that the more important of these are not mere improvements upon, or developments of, anything that had been done before, but that they are entirely New Departures, arising out of our increasing knowledge of and command over the forces of the universe. Many of these advances have already led to developments of the most startling kind, giving us such marvellous powers, and such extensions of our normal senses, as would have been incredible, and almost unthinkable, even to our greatest men of science, a hundred years ago.

It is with these new departures alone that we concern ourselves in the present volume, and to make this clear a sub-title is added in the present edition—"The Age of New Ideas." To describe, however briefly, the whole advance in the philosophy and applications of science during the nineteenth century would require an amount of knowledge and research to which the present writer lays no claim; but in the more limited and far more interesting field of the New Ideas which have rendered the last century so remarkable, it is not so hopeless a task to give a sketch which shall not be altogether inadequate.

We begin with the simplest of these advances, those which have given us increased facilities for locomotion.

Travelling at the Beginning of the Century

The younger generation, which has grown up in the era of railways and of ocean-going steamships, hardly realises the vast change which we elders have seen, or how great and fundamental that change is. Even in my own

boyhood the waggon for the poor, the stage-coach for the middle class, and the post-chaise for the wealthy, were the universal means of communication, there being only two short railways then in existence—the Stockton and Darlington, opened in 1825; and the Liverpool and Manchester line, opened in 1830. The yellow post-chaise,

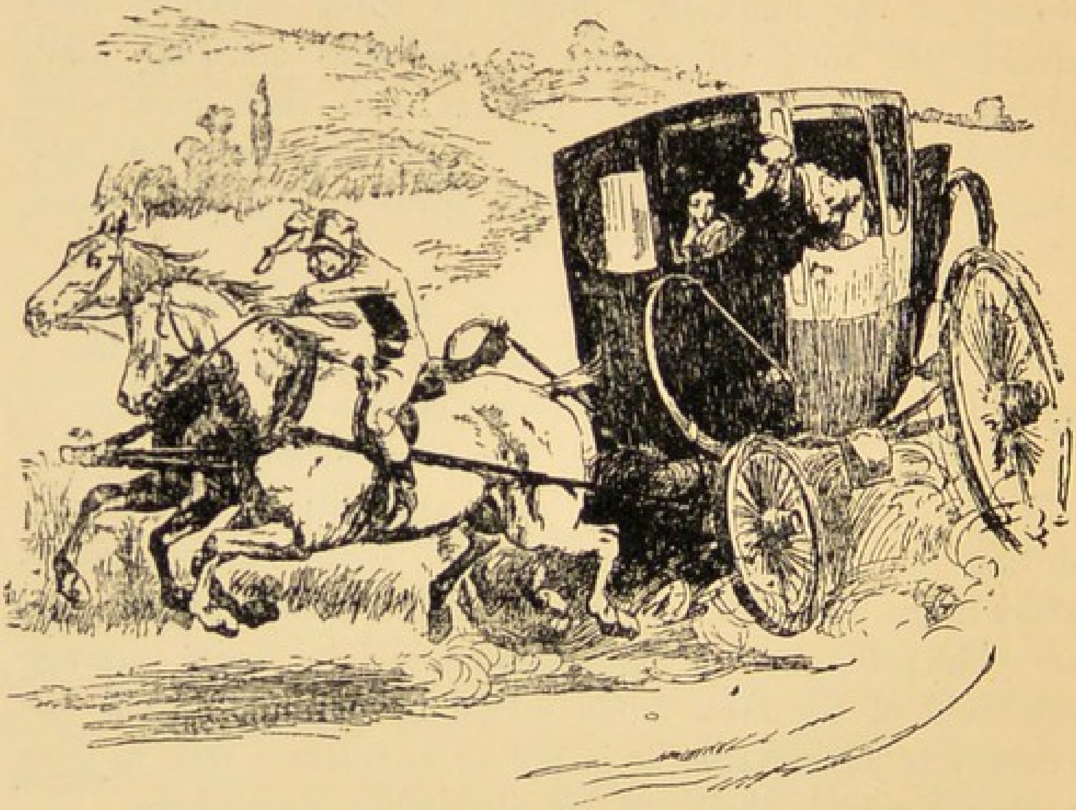


Fig. 1.—To Gretna Green in a Post-Chaise

without any driving-seat, but with a postilion dressed like a jockey riding one of the pair of horses, was one of the commonest sights on our main roads, and together with the hundreds of four-horse mail and stage coaches, the guards carrying horns or bugles, which were played while passing through every town or village, gave a stir and liveliness and picturesqueness to rural life which is now almost forgotten.

At this time all moderately-wealthy persons, and the whole of the country squires and their families, travelled post, as it was termed — that is, either in their own carriages or in post-chaises, but in both cases with hired horses and postilions, changed about every ten miles at regular posting-houses established on all the main roads, and the more important of the cross-roads as well. The chief posting-houses were considered to be of a higher class than the inns where the mail and stage coaches changed horses, and many of them did an enormous business. At the "Green Man" at Barnet twenty-six pairs of horses were kept, and a dozen postilions, who rode in blue jackets and white hats, each posting-house having its own distinctive colours. Post-horses at these large houses were kept fully harnessed day and night, with a post-boy always ready, and it is stated that on one occasion seventy-five pairs of horses were changed at the "Green Man" in the twenty-four hours, but from twenty to thirty was about the average.

The advantage of the post-chaise, and of private carriages made like it, was, that having no driver's box in front, the traveller's view of the country and of the road before him was unimpeded. It was, in fact, like a single brougham without the coachman's box; and thus, being light and carrying only two persons inside, the two good horses were able to go at ten or twelve miles an hour whenever the roads were fairly good. Hence we can understand Dr Johnston's saying that one of the greatest pleasures in life was to travel in a post-chaise.

But this was all soon to be changed by the rapid development of railways. When I first went to London (I think about 1835) there was still not a mile of railroad in England, except the two short lines already referred to, and none were even seriously contemplated

between London and any of our great northern or western cities. The sites of most of our great London railway termini were then on the very outskirts of the suburbs; Chalk Farm was a genuine farmhouse, and Primrose Hill was surrounded by open fields.

A few years later (in 1837-38) I was living near Leighton Buzzard while the London and Birmingham Railway, the precursor of the present London and North-

Fig. 2.—Third-class in 1845

Western system, was in process of construction; and when the first section was opened to Watford I travelled by it to London, third-class, in what is now an ordinary goods truck, with neither roof nor seats, nor any other accommodation than is now given to coal, iron, and miscellaneous goods. If it rained, or the wind was cold, the passengers sat on the floor and protected themselves as they could. Second-class carriages were then what the very worst of the third-class are or were a few years ago—closed in, but low and nearly dark, with plain, wooden seats; while the first-class were exactly like the bodies of three stage-coaches joined together.

The accompanying illustrations, showing the first and second-class carriages at the end of the first third of the nineteenth century, will indicate how rapid has been the

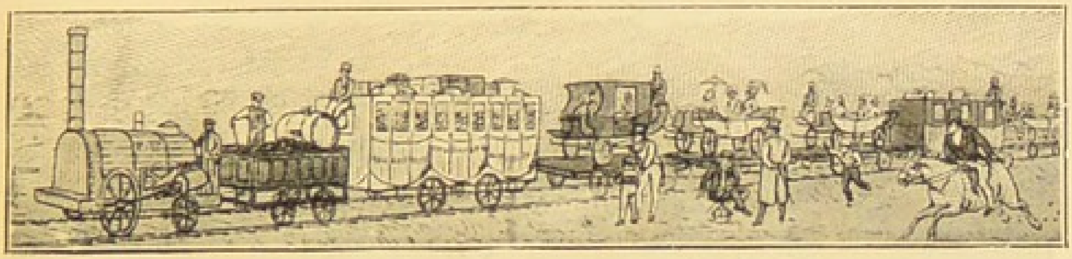


Fig. 3.—A First-class Train—Liverpool and Manchester Railway, 1833

progress in comfort and convenience during the last fifty years.

The open passenger trucks were the cause of much misery, and not a few deaths from exposure, before they were somewhat improved; but even then there was evidently a dread of making them too comfortable, so a

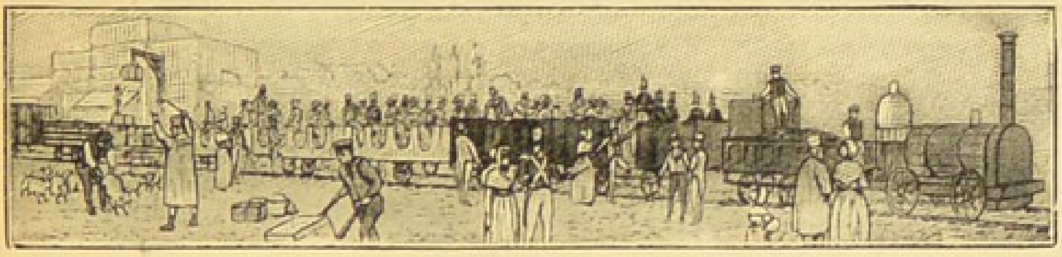


Fig. 4.—A Second-class Train—Liverpool and Manchester Railway, 1833

roof was put to them; also seats, and the sides were a little raised but were left open at the top, rendering them about equal in comfort to our present cattle trucks. At last, after a good many years, the despised third-class passengers were actually provided with carriages of the early second-class type; and it is only in comparatively recent times that the greater railway companies realised the fact that third-class passengers were so

numerous as to be more profitable than the other two combined, and that it was worth while to give them the same comfort, if not the same luxury, as those who could afford to travel more expensively.

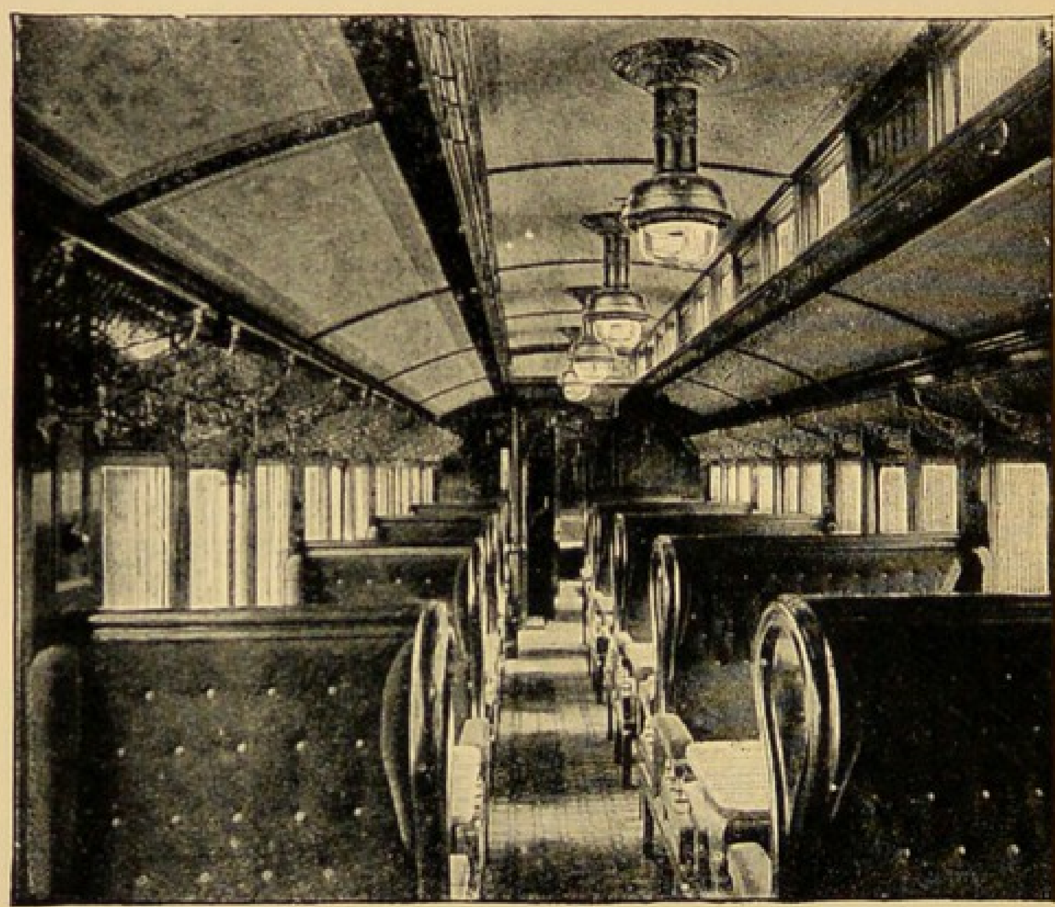


Fig. 5.—Third-class Dining-car—Midland Railway, 1900

Early Modes of Travelling

The continuous progress in speed and comfort is matter of common knowledge, and nothing more need be said of it here. The essential point for our consideration is, the fundamental and even revolutionary nature of the change that was wholly effected during the last century. In all previous ages the only modes of travelling or of

conveying goods for long distances were by employing either men or animals as the carriers. Wherever the latter were not used all loads had to be carried by men,

Fig. 6.—Ancient War Chariot

as is still the case over a large part of Africa, and as was the case over almost the whole of America before its discovery by the Spaniards.

But throughout Europe and Asia the horse was domes-

ticated in very early times, and was used for riding and in war, as shown in the accompanying spirited reproduction of an Assyrian war-chariot in action.

But chariots drawn by horses were used in peace also by all the early civilised peoples. Pharaoh made Joseph ride in a chariot, and he sent waggons to bring Jacob with his children and household goods to Egypt. A little later chariots were sent by the Syrians as tribute to Pharaoh. Homer describes Telemachus as travelling from Pylos to Sparta in a chariot provided for him by Nestor,—

> "The rage of thirst and hunger now suppress'd,
> The monarch turns him to his royal guest;
> And for the promis'd journey bids prepare
> The smooth-haired horses, and the rapid car."

It is clear, therefore, that in the earliest historic times all the various types of wheeled vehicles were used—for war, for racing, for travelling, and for the conveyance of merchandise. They must also have been used throughout a large part of Europe, since Cæsar found our British ancestors possessed of war-chariots, which they managed with great skill, implying a long previous acquaintance with the domesticated horse and his use in humbler wheeled vehicles.

Thus, throughout all past history the modes of travelling were essentially the same, and an ancient Greek or Roman, Egyptian or Assyrian, could travel as quickly and as conveniently as could Englishmen down to the latter part of the eighteenth century. It was mainly a question of roads, and till the beginning of the nineteenth century our roads were for the most part far inferior to those of the Romans. It is, therefore, not improbable that during the Roman occupation of Britain the journey from

London to York could have been made actually quicker than a hundred and fifty years ago.

Modes of Travel in England in Past Ages

So little is generally known of the actual condition of our country, and the modes of travel and communication in it for the thousand years preceding the nineteenth century, and without this knowledge it is so impossible to realise the enormous revolution which occurred in that century, that a brief sketch of the subject will not be out of place here, and will be rendered more intelligible by reproductions of a number of old drawings and engravings illustrating the modes of travel of our forefathers. This will be found to prove not only the greatness but the extreme abruptness of the change that has occurred —an abruptness which will be seen to be a feature of most of the new developments of our material civilisation which are described in the present volume.

Before the Roman occupation, roads, as we understand them, were probably quite unknown, communication being carried on by footpaths and horse-tracks; and the country being largely covered with forest, bogs, and marshes, it was very difficult for strangers to pass from one part of England to another. Both as a means of conquest, and in order to rule the country when conquered, the Romans found it necessary to make good roads, and it is remarkable how thoroughly they intersected the whole island with highways so as to afford direct communication between the chief seaports and all important places inland. The four great roads were—the Fosse, running across England from Bath to Lincoln; the Erwin Street, from London to Lincoln, Doncaster, and York; the Watling Street, from Dover through London to

Chester and to York; and the Icknield Way from Norwich by Dunstable to Southampton and into Cornwall. Besides these there were numerous cross roads, so that the whole country was rendered accessible. These roads were laid out for long distances in straight lines, with remarkable accuracy considering that at the time they were made so much of the land was covered with forest; and they were generally well constructed, all the surface soil being removed and a good foundation laid of stone or rubble, with gravel above, while the more important roads had a surface of squared blocks of stone, thus affording a pavement on which either men, horses, carts, or war-chariots could travel at a regular speed.

No other roads at all equal to these were made in England till the beginning of the nineteenth century, and it is probable that most of our great highways which follow these Roman roads got worse and worse during the Saxon and Norman periods, partly through neglect, and partly from their stone pavements being torn up and used for building, fencing, etc. In these early times good roads were quite unnecessary for the local traffic, and might often be considered dangerous as affording facilities for sudden attack by an enemy, or by armed bands of robbers. All the travel and goods-traffic of the country was carried on by riding or pack-horses. Every one above the condition of a serf or a labourer made their journeys on horseback. Ladies usually rode on pillions—a kind of chair—behind a gentleman or a servant, as here shown (Fig. 7). Weak or aged women, or the sick, were carried in litters supported on men's shoulders, or sometimes suspended between two horses; and these two modes of travel were almost universal down to the end of the fifteenth century.

During all this time the whole of the foreign goods used in England were carried from the various seaports into

the interior by pack-horses, and much of the local produce of the country, such as coal, iron, tin, wine, and the finer kinds of manufactures, was distributed in the same way. A great deal of foreign wine was imported, as well as silk and velvet, tapestries, carpets, armour, weapons,

Fig. 7.—Riding on a Pillion

spices, and dried fruits, for use in the numerous monasteries, castles, and houses of wealthy merchants; and when we consider the small weight each horse could carry, and the slow walking pace of the journey, and that this mode of traffic continued through later Saxon and Norman periods, and down to the time of Shakespeare—who mentions carriers and pack-horses as common things, but a

waggon and waggoner only as used by Queen Mab, and then evidently referring to what we should term a carriage —we shall see that the whole country must have been traversed in every direction by these trains of laden horses, the carriers travelling together in large numbers and well armed for protection against robbers. It is to the long-continued passage of these old-time itinerant traders and carriers that some of the most familiar and picturesque features of our rural districts are due. To the constant wearing away of the fixed tracks by these trains of laden horses we owe many of our deep lanes overhung by wild hedges on the top of lofty banks so common in parts of Devonshire, Surrey, and other southern counties. We can also trace to these a curious feature to be found on many of our commons and heaths — numbers of parallel roadways running side by side, sometimes a dozen or more. These often occur on a hillside and disappear at the top or on the level ground below, where there was more scope for varying the route, and where the rains did not assist in the formation of sunken tracks. Wherever these became too deep and muddy to be pleasant a new track was chosen, which was followed till it also became almost impassible, and thus in time those numerous parallel tracks were formed which sometimes have the appearance of mysterious earthworks.

Coming to the era of wheeled carriages, the first recorded use of them is in the time of King John, who is said to have used one similar to that shown in the woodcut (Fig. 8); and rude vehicles of this kind continued to be used down to the time of Queen Elizabeth, whose carriage with four wheels and a movable hood (as here shown from an old print dated 1582) is often referred to as the first "carriage" built in England (Fig 9).

This was thought to be a great improvement on all that

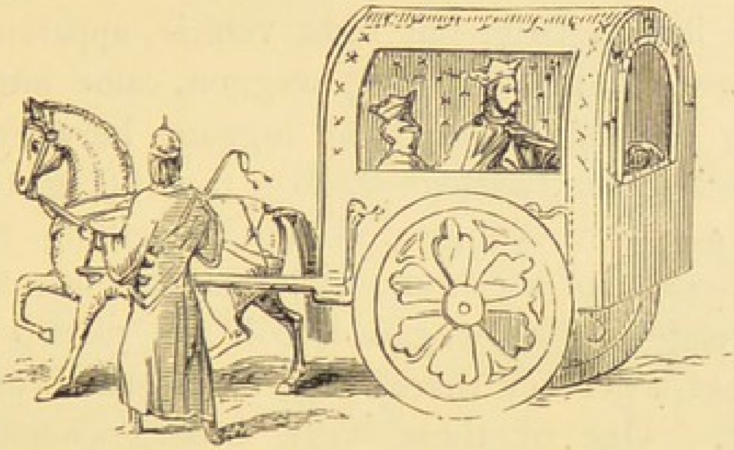


Fig. 8.—King John's Carriage

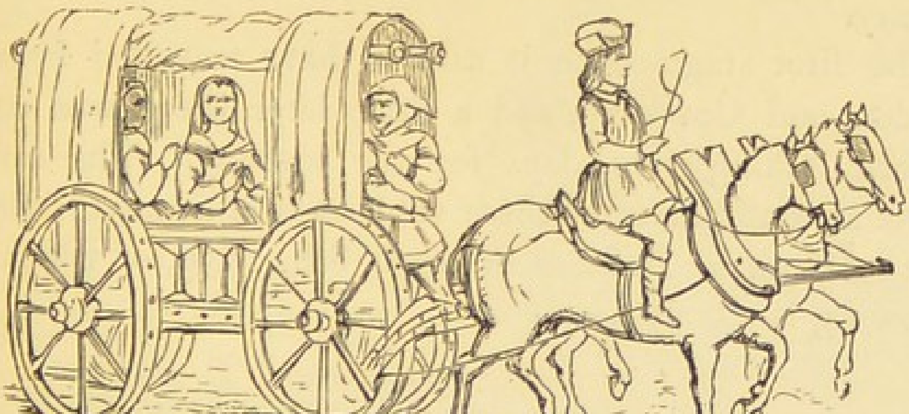


Fig. 9.—Queen Elizabeth's Carriage (1568)

had gone before, the wheels and general construction being much lighter than usual, though the absence of springs would render it rather uncomfortable according to modern ideas.

A little later a large but light vehicle, apparently made of wicker-work, called a long waggon, came into use for conveying passengers and their luggage between London and Canterbury, and some other large towns (Fig. 10). Soon afterwards this was improved into something more like the stage-coach of a century back, and in the same period heavy broad-wheeled waggons took the place of the old pack-horses wherever there were roads which allowed of their use. One of these very broad-wheeled stage-waggons, drawn by eight horses, and used for the conveyance of heavy goods and of a few of the poorer class of passengers is shown in our woodcut (Fig. 11). The immensely broad wheels helped to smooth the ruts made by the narrow-wheeled vehicles, and for this reason waggons paid very low tolls. Waggons of this type, but somewhat less clumsy, continued in use far into the nineteenth century.

The first stage-coach is said to have travelled between London and Coventry, and a little later there was one to Oxford, taking two days for the journey. The earliest public announcement of these vehicles is in an advertisement in the *Mercurius Politicus* of April 8th, 1658, of which the following is a copy :—

AN ADVERTISEMENT

"From the 26th day of April 1658 there will continue to go stage-coaches from the George Inn, without Aldersgate, London, unto the several Cities and Towns, for the rates, and at the times hereafter mentioned and declared.

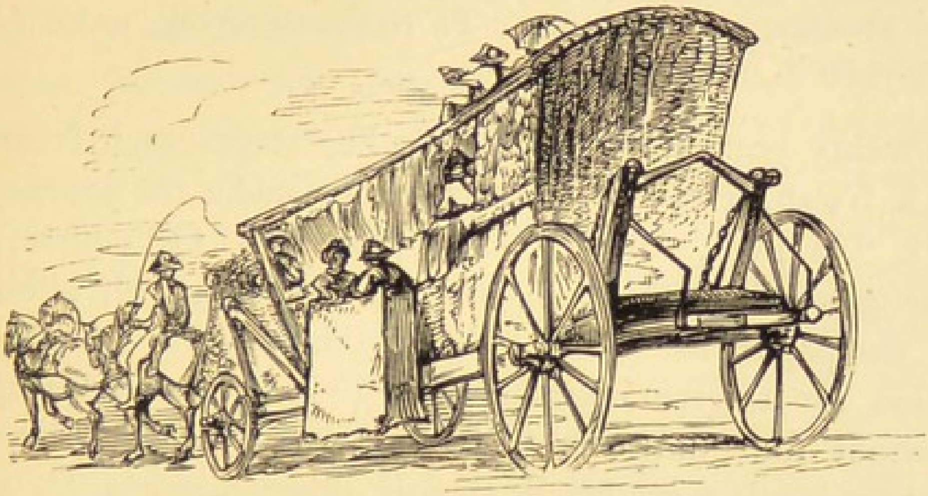


Fig. 10.—A Long Waggon, an early Public Conveyance, 1605

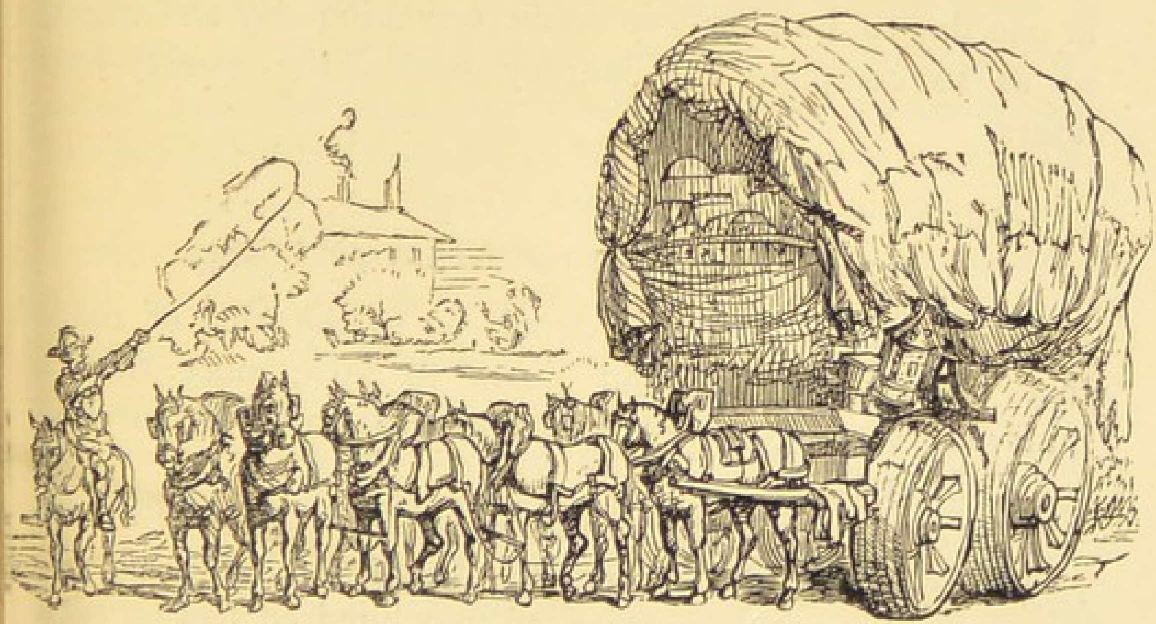


Fig. 11.—A Stage-Waggon

"Every Monday, Wednesday, and Friday.

"To Salisbury in two days for xxs. To Exeter in four days, xls. To Stamford in two days for xxs. To Newark in two days and a half for xxvs. To Bawtree in three days for xxxs. To York in four days for xls.

"Mondays and Wednesdays, to Ockington and Plymouth for ls. Every Monday, to Durham lvs. To Newcastle for iiil., to Edinburgh for ivl. a piece, Mondays."

Twenty years later (1678) another stage-coach from the Black Swan, Holborn, advertised to make the journey to York "in Four days (if God permit)." Of course, the passengers slept three nights on the road, and, allowing for stoppages for meals, the coaches were probably in motion for twelve hours a day, giving an average speed of about four miles an hour. But this showed that the northern roads were better than in other districts, for sixty years later, in 1739, the "Frome Flying Waggon with Goods and Passengers" took three days for the journey to London, 105 miles, only a little more than half the distance to York. In April 1767, however, the "Frome Stage Machine" was advertised to take "passengers and parcels" in one day to London—no doubt travelling day and night, so as to complete the journey within the twenty-four hours.

Our Roads down to the Nineteenth Century

We will now give a few details as to the kind of roads that prevailed in England down to little more than a hundred years ago, and which rendered travelling so slow and difficult.

One of the first Acts relating to highways was in the reign of Edward I. It enacted that in all highroads between market-towns, a space of two hundred feet on each side should be kept clear of wood and bushes, chiefly to

prevent robbers from lurking in them, but it would also have the effect of keeping the roads dryer, and enabling travellers to turn aside from impassable mud-holes or other obstacles.

In an Act for altering certain roads in Kent and Sussex in the reign of Henry VIII., it is stated, that the roads have "become so deep and noyous by wearing and course of water, that people cannot travel on them but to their great pain, peril, and jeopardy." In 1663, in an Act for establishing tolls on the north road from London to York, it is said that the road from London to Cambridge, owing to the great and heavy traffic over it, has "become almost impassable, insomuch that it is very dangerous to all his Majesty's liege people that pass that way."

Towards the end of the seventeenth century an Act declared that many highways remain almost impassable, and enacted that all cartways between market-towns were to be eight feet wide at least, and kept even and level, and that no causeway for horses was to be less than three feet in breadth. These narrow causeways were probably in many cases the old Roman paved roads, and others made in imitation of them, and their existence, to some extent, saved the wider roads for wheeled carriages from injury. But the efforts to keep these latter in repair were of little avail, as shown by the fact that travelling in winter was almost impossible. The Rev. Mr Brome, who wrote a book describing a three years' journey over Britain from Cheriton in Kent, began his journey in 1700, "as soon as the spring had rendered the roads passable"; and having explored the southern districts during the summer, in the autumn found himself at Brentford, where he wintered and waited for the spring! He penetrated even into the Highlands of Scotland, where he found the country still infested with wolves, which were very mischievous.

In an account of an equestrian journey from Glasgow to London in 1749, it is stated that there were no turnpike roads till within 110 miles of London. Up to that point horsemen travelled on narrow causeways with an unmade soft road on each side of it. They met gangs of pack-horses following each other in a line led by an old horse carrying a tinkling bell. Upon meeting these, the travellers had to leave the road to allow them to pass.

The condition of the roads, in most parts of England, is well shown by an account of the journey of Prince George of Denmark from Windsor to Petworth, in December 1703, written by one of his attendants: "We set out at six o'clock in the morning to go for Petworth, and did not get out of the coaches (save only when we were overturned or stuck fast in the mire) till we arrived at our journey's end. 'Twas hard service for the Prince to sit fourteen hours in the coach that day without eating anything, and passing through the worst ways that ever I saw in my life. We were thrown but once, indeed, in going, but both our coach, which was leading, and his highness's body coach, would have suffered very often, if the nimble boors of Sussex had not frequently supported it with their shoulders from Godalming almost to Petworth; and the nearer we approached the Duke's house the more inaccessible it seemed to be. The last nine miles of the way cost us six hours' time to conquer them, and, indeed, we had never done it if our good master had not several times lent his pair of horses out of his own coach, whereby we were enabled to trace out his way for him. They made us believe that the several grounds we crost and His Grace's park, would alleviate the fatigue, but I protest I could hardly see any difference between them and the common road."

Later still, in 1767, the great agricultural writer,

Arthur Young, found "the roads in Essex so narrow that not a mouse could pass the carriage, and ruts of an incredible depth; waggons stuck fast and requiring twenty or thirty horses to draw them out."

The same traveller describes a road in Lancashire in the following manner:—"I know not in the whole range of language terms sufficiently expressive to describe this infernal road. Let me most seriously caution all travellers who may propose to travel in this terrible country, to avoid it as they would the devil; for a thousand to one they break their necks or their limbs by overthrows or breakings down. They will here meet with ruts, which I actually measured, four feet deep, and floating with mud only from a wet summer; what, therefore, must it be in winter? The only mending it receives, is tumbling in some loose stones, which serves no other purpose than jolting a carriage in the most miserable manner. These are not mere opinions but facts; for I actually passed three carts broken down in these eighteen miles of execrable memory."

This condition of even our great highways continued to be very general till the early part of the nineteenth century, owing chiefly to the ignorant way in which the roads were repaired by merely filling up mud-holes with stones and gravel of whatever kind was most easily to be obtained. Before a Parliamentary Committee in 1808, Mr Waterhouse, a large coach-proprietor, stated that he had often known the road across Hounslow Heath to be two feet deep in mud. In 1798 one of the fastest coaches took nineteen hours to travel the eighty miles from Gosport to Charing Cross, or a little over four miles an hour. At this time the best of the main roads appears to have been that between London and Manchester, on which the mail coaches ran at an average speed of six and three-quarter miles an hour,

It was only during the first quarter of the nineteenth century that the roads of our country came to be what we now find them, chiefly through the talents and energy of two men—Telford, the great bridge and road maker, who re-constructed many of our main roads with special attention to easy gradients and a solid foundation; and Macadam, who brought about the adoption of the method of using stone broken to a uniform size as being essential to the formation of a smooth, hard and durable surface. It is certainly a curious fact that the first application of scientific methods to ordinary road-making occurred in the early part of the same century which a little later saw our coaches and waggons, for whose use these improvements were made, almost wholly superseded by railways. And even when the first of the great railways was in process of construction, about the year 1839, so little idea was there that the great highways would not much longer be required for the conveyance of the mails and passengers, that the roads were in many places being still further improved at great expense. About the time mentioned I visited Dunstable, near which town the great North-Western Road passes through a deep cutting in the chalk downs. Hundreds of workmen were at that time employed in deepening this cutting some eight or ten feet, to make the gradient easier for stage and mail coaches, which, in less than twenty years more had entirely ceased to run.

This brief account of the modes of travel from the earliest times till the construction of our great railways in the second quarter of the present century shows that there had been absolutely no change in the methods of human locomotion; and that the speed for long distances must have been limited to ten or twelve miles an hour even under the most favourable conditions, while generally

it was very much less. But the railroad and steam locomotive, in less than fifty years, not only raised the speed to fifty or sixty miles an hour, but rendered it possible to carry many hundreds of passengers at once with punctuality and safety for enormous distances, and with hardly any exposure or fatigue. For the civilised world, travelling and the conveyance of goods have been revolutionised, and by means which were probably neither anticipated nor even imagined fifty years before.

Dr Erasmus Darwin, who predicted steam carriages, had apparently no conception of the construction of railroads, the enormous cost of which would have seemed to him prohibitory. And we have by no means yet fully developed their possibilities, since even now a railroad could be made on which we might safely travel more than a hundred miles an hour, it being merely a question of expense. A short account of the origin of our railway system will now be given, as its early history is almost entirely unknown to the younger portion of the present generation.

Early History of Railways

The forerunners of our railways were the tramways used in the colliery districts of the North of England so early as the seventeenth century. In a letter written by Roger North from Newcastle in 1676 he describes the "rails of timber from the colliery down to the river, with wheels or rollers to fit them, whereby the carriage is so easy that one horse will draw four or five chaldrons of coals." In the next century such trams became general in all mineral districts; and as the wood wore out quickly cast iron rails were first laid on the wooden bearers, and afterwards on cross-sleepers of wood or on blocks of

stone. With these iron rails two horses were able to draw twenty-four tons. In the year 1805 a tramroad for heavy goods was made between Wandsworth and Croydon. On this line a single horse drew twelve waggons laden with stones, thirty-six tons in all, at about four miles an hour. It was found that even fifty tons could be thus drawn by a single horse.

The Stockton and Darlington Railway, which was opened in 1825, was the first passenger railway in England, but it was really a horse-tramway, on which passengers were carried in coaches of the usual type. It was, however, thirty-seven miles long, and the coaches were drawn at the rate of ten miles an hour by a single horse, so that it illustrated the advantages of rails in facilitating locomotion on a scale which had never before been attempted.

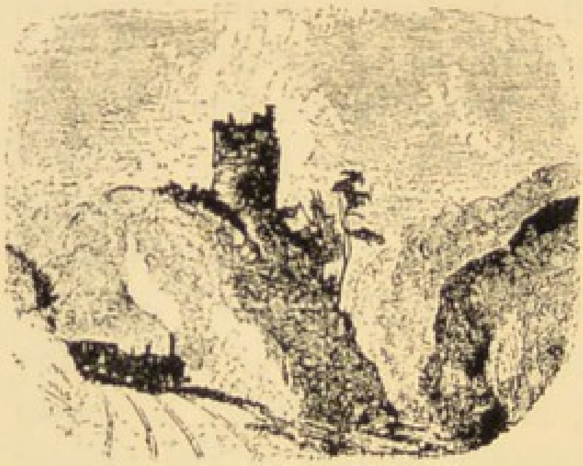


Fig. 12.—Woodhouse Tower, Caledonian Railway — The Old World and the New

But, although the great value of iron roads was thus demonstrated, the locomotive engine as a substitute for horse-power was hardly dreamt of till George Stephenson showed it to be a practicable reality. It is said, indeed, that a Mr Murdoch of Redruth, in Cornwall, actually constructed a locomotive in 1784, but, if so, it was too imperfect to come into use. Another Cornishman, Trevethick, the inventor of the high-pressure steam-engine, was the first who constructed a successful locomotive, which worked for some time in South Wales, drawing

a train of coal waggons at the rate of five miles an hour, It was also tried in London in 1803; but its inventor was not satisfied with it, and, instead of waiting to improve it, he went to the West Indies and South America, and only returned to England when Stephenson, after many trials, had completely succeeded. He first built a loco-

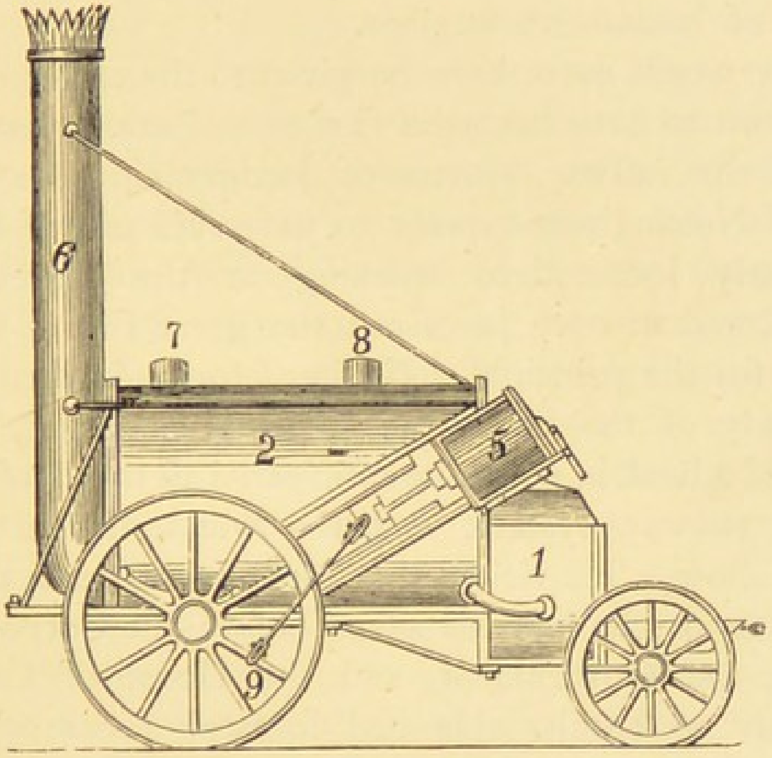


Fig. 13.—"The Rocket" Locomotive

motive in 1814, for the Ravensbourne Collieries, and others which were used on the Stockton and Darlington line, but none of these worked quite satisfactorily, owing to the difficulty of keeping up the great supply of steam required when travelling at more than five or six miles an hour. He at length solved the problem by turning the waste steam into the chimney, which, condensing as it reached the top, produced a partial vacuum, and a powerful draught through the furnace. The more rapidly the engine worked,

the greater became the draught, and the hotter the fire, thus enabling the "Rocket" to surpass all other locomotives which competed with it. Fig. 13 shows the main features of this celebrated machine, which may be termed the first successful railway engine. The very simple arrangement by which the draught is kept up automatically is now universally adopted, and is really essential to the success of locomotive engines.

A few words must here be given to the career of a man who seems to have been the first to realise the vast importance of the railway system of locomotion. Mr Thomas Gray of Nottingham appears to have seen one of Stephenson's early locomotives working at the Ravensbourne Colliery, and at once perceived the great future that was in store for the principle. He henceforth devoted himself to a study of the subject in all its aspects, and, in 1820, published a book in which he anticipated all the chief features of our railway system, and the wonderful results that would follow. He visited the chief seaports and manufacturing towns; he laid his plans before the Corporation of London, the Government, and the House of Commons, but with no result. He had foreseen too much. And though all his plans were fully realised only thirty years later, the man who urged that they should be systematically carried out was universally scouted as a mad enthusiast, and was allowed to die in extreme poverty when his predictions had been already realised! Well did Charles Mackay write:

"The man is thought a knave or fool,
  Or bigot plotting crime,
Who, for the advancement of his kind
  Is wise before his time.
For him the hemlock shall distill;
  For him the axe be bared;
For him the gibbet shall be built;
  For him the stake prepared.

Him shall the scorn and wrath of men
  Pursue with deadly aim ;
And malice, envy, spite, and lies,
  Shall desecrate his name.
But truth shall conquer at the last,
  For round and round we run ;
And ever the Right comes uppermost,
  And ever is Justice done."

It was probably the result of Gray's book, and of his personal advocacy at Manchester, when he urged upon its manufacturers the enormous benefit they would derive from cheap and rapid communication with the sea, that a railway from Liverpool to Manchester was proposed in 1822, and an Act of Parliament for its construction obtained in 1826. The opposition, however, was very great, so that, when it was finally decided to use locomotive engines, it was considered advisable to propose no greater speed than ten miles an hour, although Stephenson was quite sure his engine could go twenty miles with perfect safety.

The early builders of locomotives had to encounter the great difficulty of having to work with extreme delicacy on a large scale, without the assistance of that wonderful series of machine-tools which now introduce into the largest steam-engines the accuracy of dimensions and the truly plane or curved surfaces of a theodolite or a chronometer. This has been attained, step by step, from the days of James Watt; and it alone has rendered possible the rapid alternate motions of the piston and valves, free from all jars, and with perfect smoothness, that now enables us to travel more than sixty miles an hour with comfort and safety.

Early Objections to Railroads

A few words may usefully be devoted to giving some idea of the senseless opposition made to railroads, as it may help us to see that much of the opposition to other reforms is equally the result of prejudice or ignorance.

The *Quarterly Review* embodied the ideas of the educated public of the period, when it declared, in 1824, that—"As to those persons who speculate on making railways throughout the kingdom, and superseding all the waggons, mails, and stage-coaches, post-chaises, and, in short, every other mode of conveyance by land and by water, we deem them, and their visionary schemes, unworthy of notice." And, again, in 1825, when it was proposed to make a railway from London to Woolwich, and to travel on it "at twice the speed of stage-coaches with greater safety," the reviewer remarked: "We should as soon expect the people of Woolwich to suffer themselves to be fired off upon one of Congreve's *ricochet* rockets, as trust themselves to the mercy of such a machine, going at such a rate."

When the first great railways from London were in contemplation, much fear was expressed of injury by them, one of the most fantastic being that of the town of Northampton, which objected to have a railway and station there, on the ground (among others) that the smoke from the engines would injure the wool of the sheep! The Birmingham line had, therefore, to pass four miles from the town; but, subsequently, a branch was found necessary, then a loop-line, and now trains enter Northampton from six directions, and, all together, do not, probably, cause so much smoke as the chimneys of its factories.

In Parliament, the opposition was very fierce, and often

quite ludicrous. One Member asked: "Was the House aware of the smoke and the noise, the hiss and the whirl, which locomotive engines, passing at the rate of ten or twelve miles an hour, would occasion?" And he concluded, that—"It would be the greatest nuisance, the most complete disturbance of quiet comfort in all parts of the kingdom, that the ingenuity of man could invent." Another Member urged that — "Such schemes were dangerous, delusive, unsatisfactory, and, above all, unknown to the constitution of the country"; that "he hated the very name of a railway — he hated it as he hated the devil."

When the *Great Western Railway* Bill was before Parliament, the representatives of Eton and Oxford obtained the insertion of special clauses, prohibiting the formation of any branch to Oxford, or even of a station at Slough, as being too near to Eton. Medical men also were found who alarmed the public by asserting that the tunnels would be dangerous in producing catarrhs and consumption; and that the deafening noise, the fearful gloom, the clanking chains, the dismal glare of the locomotive, were so alarming, that such inventions ought not to be allowed. Yet less than ten years later, the great railway mania occurred. Lines were proposed in every possible direction; opposition companies, started, in order to be bought off; all the civil engineers and surveyors in the kingdom were employed, at high salaries, to prepare the necessary plans for Parliament; and all over the country, high and low, rich and poor, bought shares in the various new railways that were proposed, or were making. During this speculative mania, fortunes were gained and lost, numbers of useless lines were constructed, and that system of competing lines initiated which has brought about the hopeless confusion and inconvenience that pervades our existing railway

system. The great railway mania of 1845 is almost unknown to the present generation, but it led to the rise of that body of promoters and speculators, with all their satellites and assistants, which, fostered later on by the possibilities afforded by the Limited Liability Act, have continued to increase till they have now become one of the greatest dangers to our social system.*

Canals and Railways

Before leaving this branch of our subject, it may be well to say a few words on our canal-system, and how it has been affected by the growth of railways. Our earliest canals—the Foss Dyke and Caer Dyke, in Lincolnshire—were made by the Romans, and improved in the twelfth century; but the Aire and Calder Navigation, between Goole and Leeds, constructed near the end of the seventeenth century, was the first important step towards the improvement of our inland navigation. Our great canal-making period was, however, during the latter half of the eighteenth century, and in 1791-94 there occurred a kind of canal mania, when many canals, some of very little use, were initiated. The last inland canal constructed in England was completed in 1834; and, during the whole period of canal-building, there was evidently no conception whatever of the impending new system of land-carriage,

* The present writer was engaged in surveying one of these lines proposing to run from Swansea to Yarmouth, and thus connect the east and west coasts of England. In order to finish the plans and reference books required by Parliament, about a dozen of us—engineers, surveyors, and lawyers—lived at a large hotel in the Haymarket, where for the last two or three days we worked day and night to be in time, and ordered whatever we liked in the way of food and wines to keep up our working powers. Of course the Act for this line was not obtained, and I believe it was withdrawn in favour of some partially competing lines whose shareholders had to pay our expenses.

which should soon render many of them almost useless. It appears, from the Board of Trade Returns, that the total capital of the canal companies in England and Wales is about £32,000,000, and that, on nearly £10,000,000 of this no dividend or interest is paid, and on about £5,000,000 more less than 3 per cent. These canals and navigations have a total length of 2208 miles; while canals to the length of 959 miles have been bought by the various railway companies. These last are mostly in the mineral districts of England and Wales.

The way these canals have been affected by the railways may be illustrated by the case of the Grand Junction Canal, 188 miles long, and connecting the midland counties with London. In 1837, when the London and Birmingham Railway was being constructed, the traffic of the canal was 1,100,000 tons; in 1850 it had fallen to 1,000,000 tons, no doubt through the competition of the railways; but by 1900 it had risen again to 1,627,000 tons; but the General Manager of the Company, to whose courtesy I am indebted for these figures, informs me that the increase is wholly due to local traffic between places near the canal, the through traffic from the Midlands to London having greatly fallen off since 1854.

The disadvantages of inland canals are (1) the slow rate at which the boats must travel so as not to injure the banks; (2) the difficulty of obtaining an ample supply of water on the summit-level when there are locks; and (3) the great loss of time in passing the locks when they are numerous. The advantages are, however, correspondingly great. (1) The first cost, repairs, and working expenses of canals are very small; (2) the horse or steam-power required per ton is very low—a single horse being able to draw forty tons at two miles an hour. But when locks are numerous, as much time is lost passing them as in

travelling along the free water-surface; to obviate which various substitutes have been adopted, such as inclines, or lifts, in both cases with an arrangement by which the descending boat balances the ascending one, and renders the extra power required comparatively small. In these cases, the canal is so laid out as to have only a few steps, with a considerable rise or fall at each of them, instead of a great many small steps, when locks are used. But these methods are more costly than locks, and still cause a considerable delay. To utilise canals to the utmost, boats should be able to succeed each other closely in an almost continuous stream from one end to the other, all, of course, travelling at the same rate, and being of the same size; while the ascent and descent of the inevitable inclines should be so arranged as to work automatically, and involve a very small delay. It is very unfortunate that so short an interval elapsed between the canal and the railway epochs. Had a century intervened, there would, no doubt, have been many improvements in canal navigation, which will now, perhaps, never be made.

The Modern Cycle

Almost as remarkable as our railroads and steam-ships is the new method of locomotion by means of the bicycle and tricycle. The principle is an old one, but the perfection to which these vehicles have now attained has been rendered possible by the continuous growth of all kinds of delicate tools and machines required in the construction of the infinitely varied forms of steam-engines, dynamos, and other rapidly-moving machinery. In the last century it would not have been possible to construct a modern first-class bicycle, even if any genius had invented it, except at

a cost of several hundred pounds. The combination of strength, accuracy, and lightness would not then have been obtainable.

The forerunner of the bicycle was the old hobby-horse, or dandy-horse, first used in the eighteenth century, but improved in the early part of the nineteenth, when it was used under various names in France, Germany, and England. The motive power was the alternate push backwards on the ground of the feet of the rider, so that, by an active person on a good road, a considerable speed could be attained without much fatigue, and about the year 1820 a good many were in use in England.

But the first true bicycle, as we now understand the term, was made by a Scottish cooper, named Dalzell, in 1836. This machine had all the essential features of the modern safety bicycle, and, though rude and heavy, the maker used it so effectively that he easily beat the mail-coach for a distance of ten miles, which was covered within the hour.

For many years little was done except in the construction of a number of three or four-wheeled machines, worked by the hands, which never came into general use. But about 1868 an improved bicycle was made in France, and was imported into England and America, and from that date commenced the era of continuous improvement in every detail of construction and arrangement of parts, which has resulted in the beautiful machines now in common use. These improvements consist mainly in increased lightness and strength, by the use of steel tubes in the frame, and by using strained wire instead of spokes to connect the tube with the rim of the wheels. Friction is diminished by the use of ball-bearings for the axles to run on, and the most accurate workmanship throughout; while the jolting and jarring which caused the early cycles to be christened

"bone-shakers" was greatly reduced by the use of solid or hollow rubber tyres, but has now been almost completely overcome by the pneumatic tyres, first used in 1888, and since improved so as to be now almost ideally perfect.

Men, women, and children of all ages now ride bicycles,


Fig. 14.—A Lady Cyclist, 1900

and many are thus able to travel from fifty to a hundred miles in a day with less fatigue than most of them would feel in walking ten or twenty miles; while the pleasure and exhilaration of such rapid motion, by means of their own moderate exertion, are so great as to induce many persons to take healthy out-of-door exercise to whom walking is tiring or distasteful, and horse-riding unattain-

able. In cycling we have thus acquired an altogether new power, whose exercise is at once pleasurable and health-giving; while the trained cyclist becomes as much a part

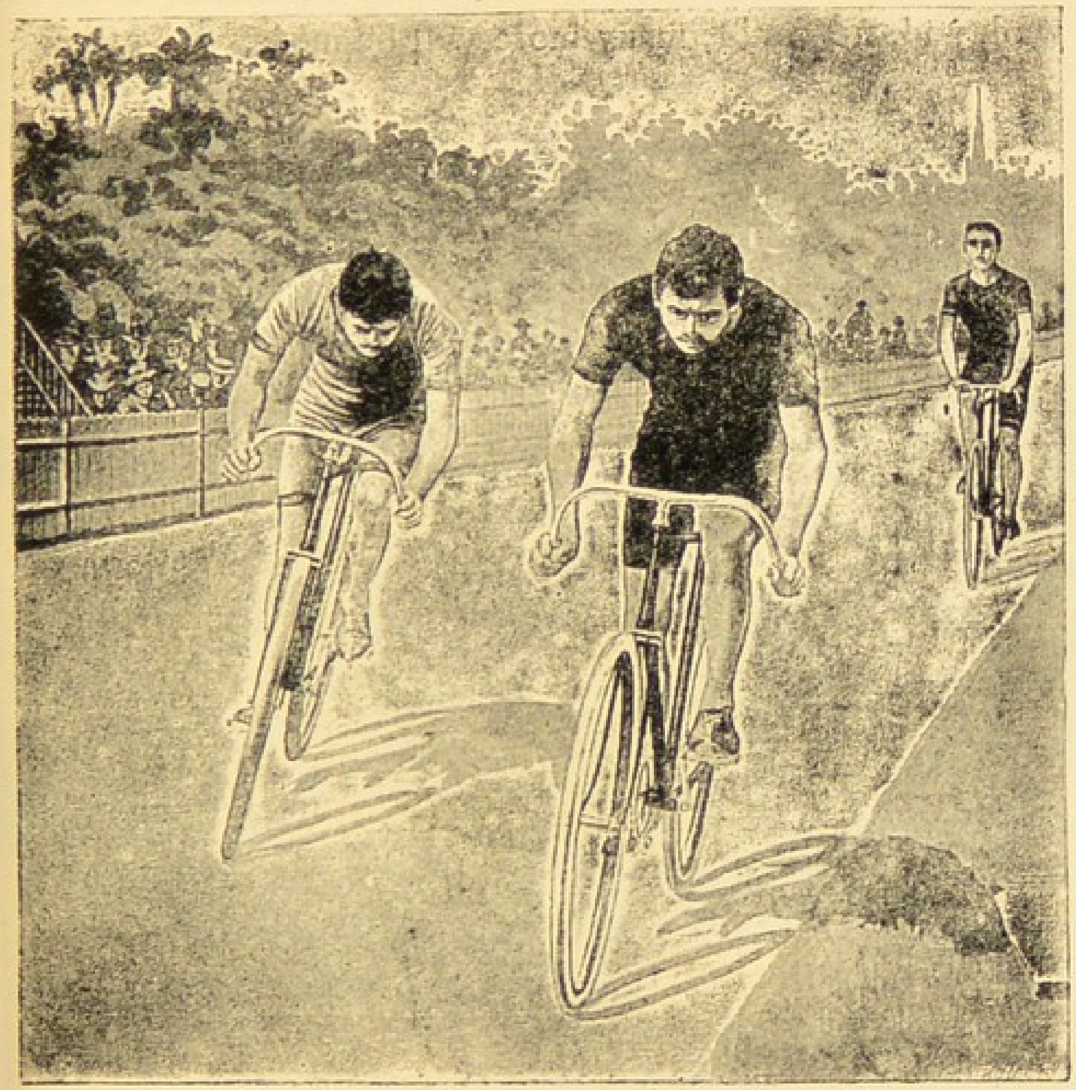


Fig. 15.—A Cycle Race, 1900

of his machine as is the skilful rider of his horse, automatically guiding it through a crowded street, or avoiding the various inequalities of a country road so that he seems to have acquired a new faculty, as well as an enormously increased power of locomotion (Figs. 14 and 15).

The number of trials and failures required before these

results were obtained may be estimated by the fact that, in the year 1884, no less than 220 distinct kinds of tricycles were on sale, so that the number of different constructions of bicycles and tricycles has probably been over a thousand, and, no doubt, many more will be made.

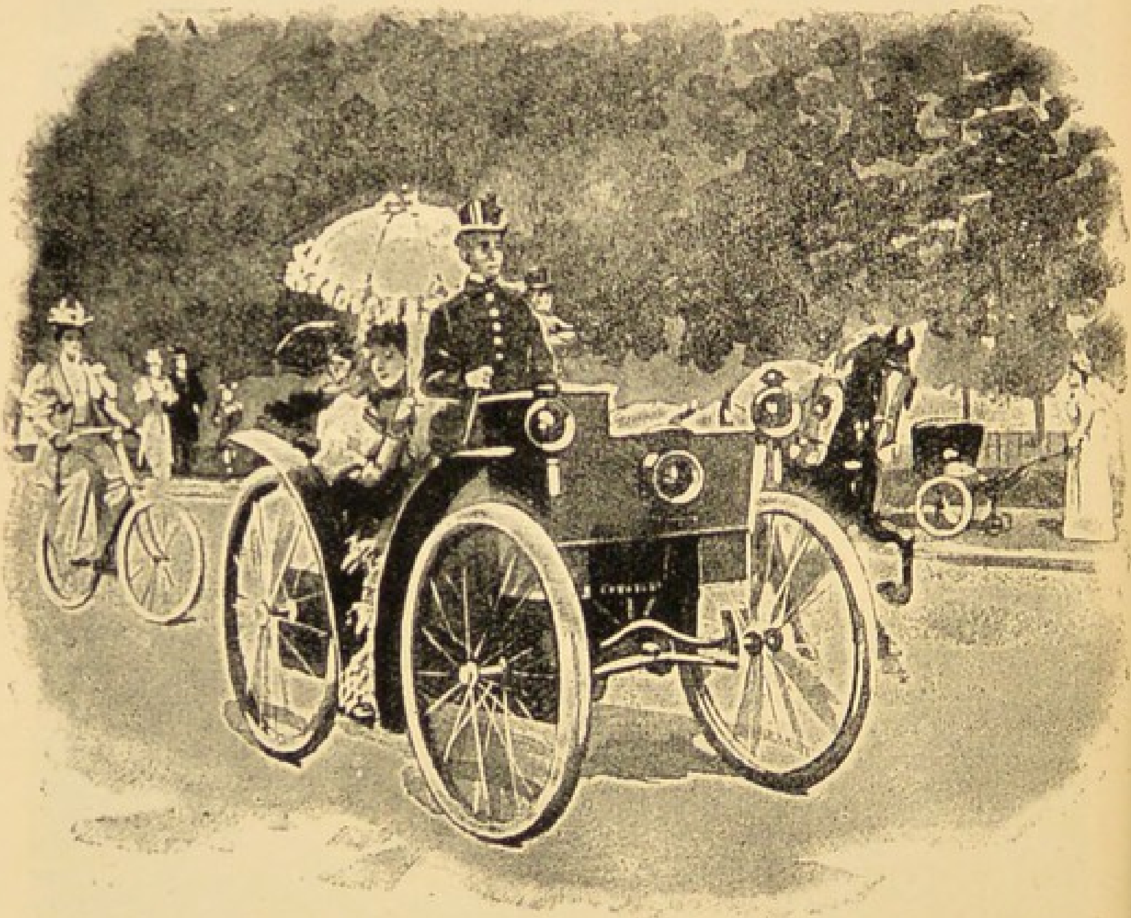


Fig. 16.—A Motor Carriage, 1900

It is very interesting to note that three out of the four methods of rapid locomotion we now possess should have attained about the same maximum speed. The racehorse, the steamship, and the bicycle have each of them reached thirty miles an hour. The horse is, however, close upon, if it has not actually attained, its utmost limits; the bicycle can already beat the horse for long distances, and will

certainly go at higher speeds for short ones; while the steamship will also go much quicker, though how much no one can yet say.

It is certainly a most wonderful and unexpected fact that, while the fastest athletes have not been able to run twelve miles in an hour, a mode of progression should have now been perfected by means of which any fairly strong and healthy person can exceed that speed for several successive hours. With comparatively little fatigue, most good cyclists can travel, over fairly good roads, about a hundred miles in a day, while only a few could walk even fifty miles without very much greater labour. The cycle is thus shown to be a new departure, unlike anything that has gone before it.

More recently, cycles, and various forms of carriages have been made, which are propelled by either steam, gas, petroleum, or electricity; but, as these are in principle identical with the steam-locomotive, they need not be further discussed here (Fig. 16). They have, however, a very important bearing on the health and pleasure of those who live in towns, because, as soon as they are sufficiently improved to supersede horse-power, all streets and roads within town limits can be asphalted; and, with the universal use of rubber-tyres, they will be rendered both noiseless and almost indestructible, while, by a daily sluicing, they may be kept as clean and wholesome as the floors of a dwelling-house. This is one of the great improvements that the twentieth century will probably carry out, and which some who read these lines will probably live to enjoy.

CHAPTER II

THE ADVANCE IN LOCOMOTION ON THE OCEAN

"How gloriously her gallant course she goes!
Her white wings flying—never from her foes—
She walks the waters like a thing of life,
And seems to dare the elements to strife."
BYRON.

In man's power of travelling over the vast and trackless oceanic wastes, there has been a very similar course of events to that exhibited on land. From the very dawn of history, and even far back in pre-historic times, men used rowing or sailing boats both on rivers and seas, keeping mostly along the coasts from one harbour to another. One of the earliest boats for river navigation and fishing—the coracle—still survives in a few places in Wales and Ireland. At my native place, Usk, in Monmouthshire, it was in common use in my childhood, and we often saw fishermen in them on the river Usk, or carrying them on their backs, as shown in the illustration (Fig. 17). They consisted of a strong, shallow wicker basket of an oval shape, about four feet long and three feet wide, covered with raw hide. The coracle is deeper behind, where there is a seat, and it is rowed by a single paddle, as are the canoes of most savage peoples. In this form it carries one man only, but they were sometimes made larger, to carry two men, and fitted with mast and sail. Even voyages across the North Sea and the Irish Channel are said to have been made in them. They were described by Cæsar, and furnish a

striking example of a very peculiar type of boat remaining in use for two thousand years without change.

Boats were also formed from trunks of trees hollowed out by cutting-tools or by means of fire, and these were gradually improved by adding planks to raise the sides till, as early as the time of Homer, good-sized ships were built

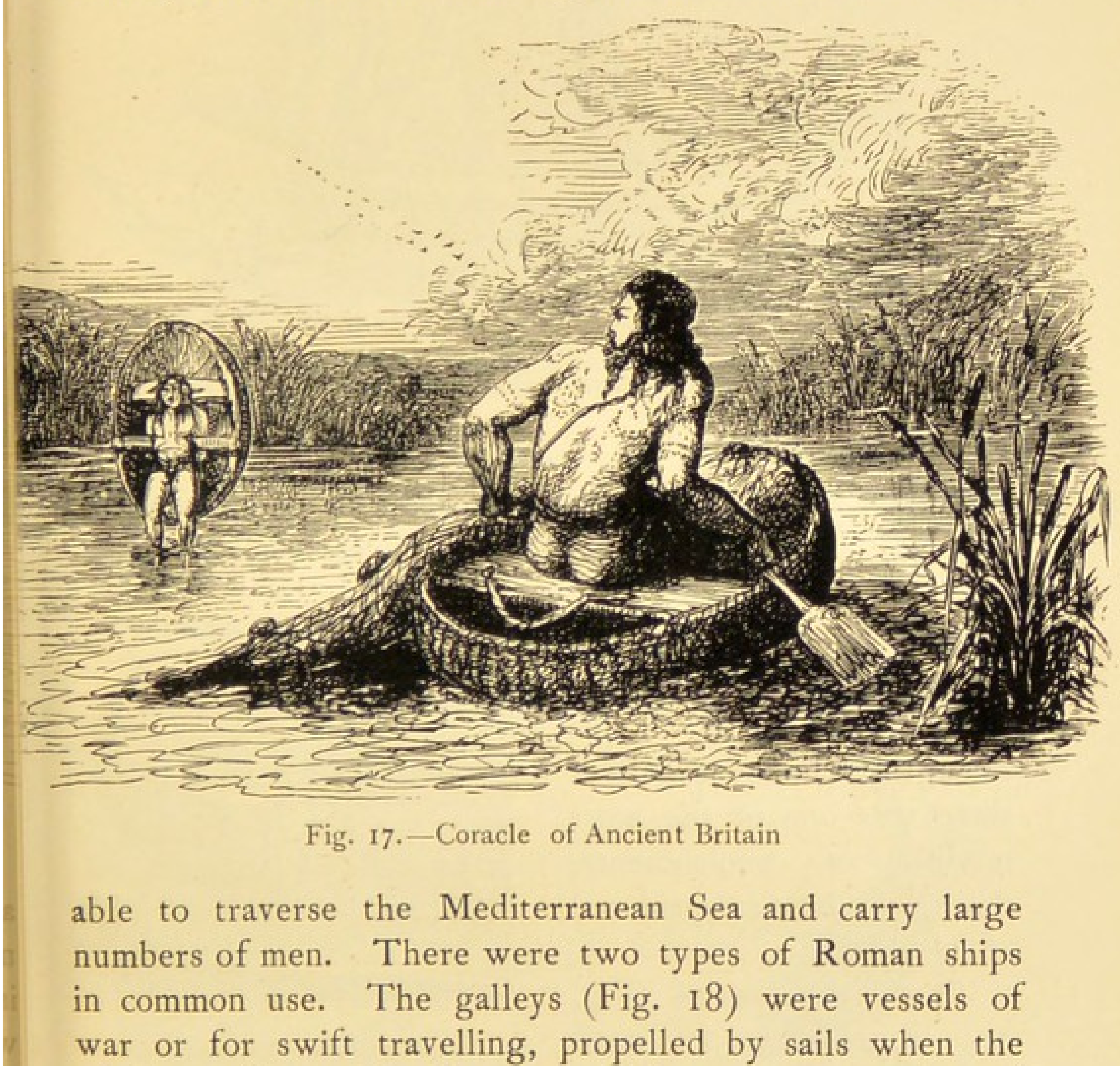


Fig. 17.—Coracle of Ancient Britain

able to traverse the Mediterranean Sea and carry large numbers of men. There were two types of Roman ships in common use. The galleys (Fig. 18) were vessels of war or for swift travelling, propelled by sails when the wind was favourable, but assisted by a large number of rowers, which enabled them to travel as quickly as an old-fashioned steamship. Some of the war - galleys were manned by two, three, or even four banks of rowers on

each side, the highest oars being very long and heavy, requiring several men to each oar. The triremes, or three-

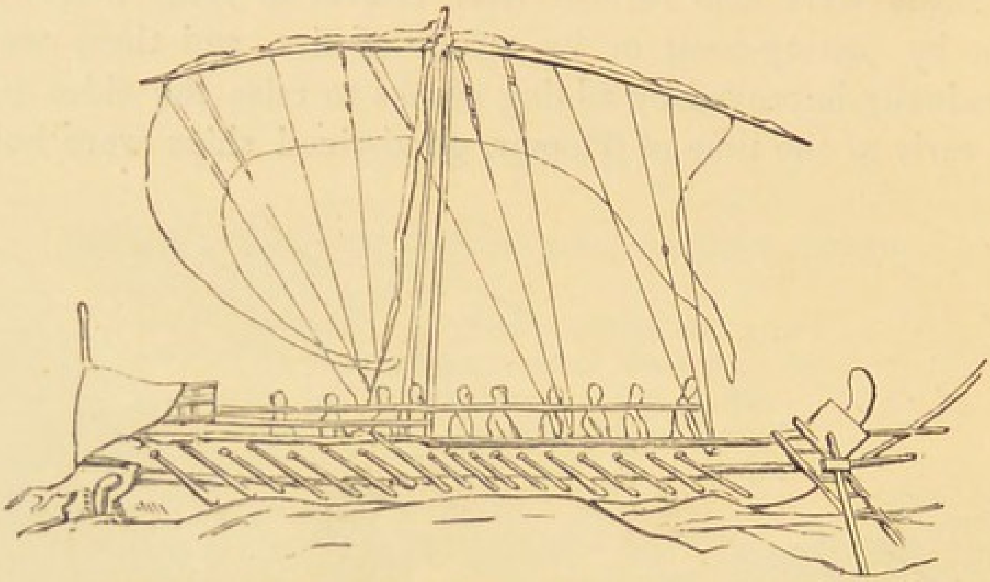


Fig. 18.—Small Roman Galley (from Trajan's Column)

banked galleys (Fig. 19), were 105 feet long and 11 feet wide, the quadriremes, with four rows of oars, were 125 feet long and 13 feet wide. These rowers were all slaves; they were chained to their seats, and overseers with whips lashed anyone who did not pull with all his strength. To be a galley-slave was one of the most terrible of punishments, their lives being considered of no value.

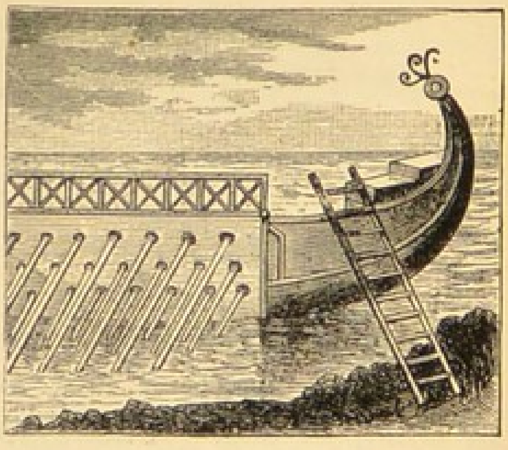


Fig. 19.—A Three-Banked Galley

The other vessel (Fig. 20) represents a small Roman merchant ship propelled by sails only, and steered by means of a large paddle slung at the stern in the manner still used by the Malays in their Prahus. A Norman ship, as shown on the

Fig. 20.—Roman Merchant Ship (from Trajan's Column)

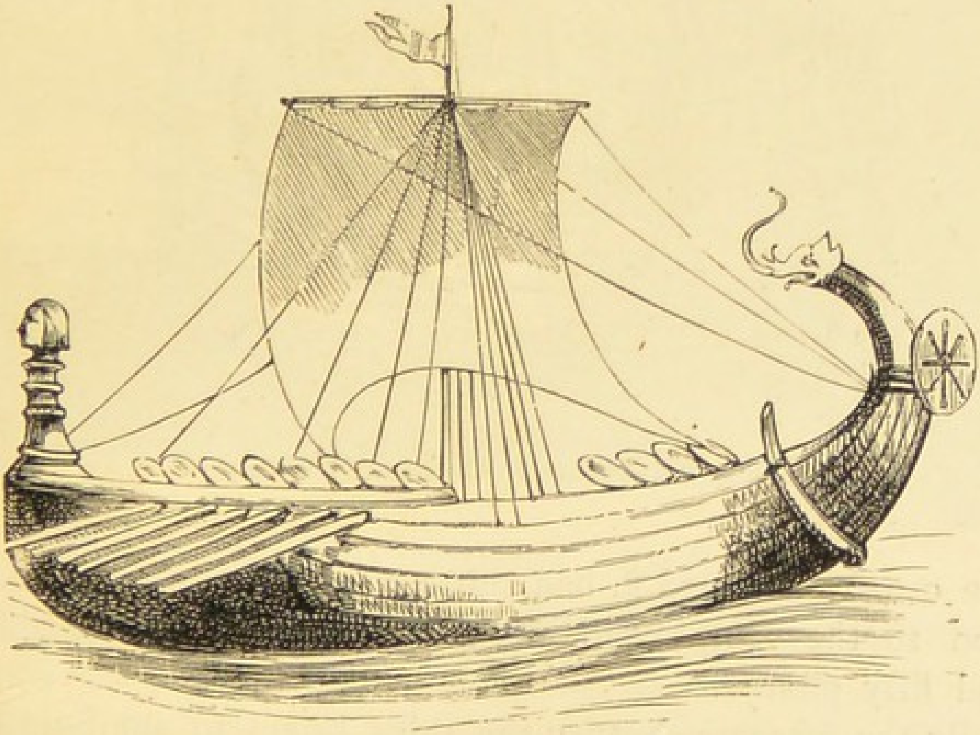


Fig. 21.—Norman Ship (from Bayeux Tapestry)

Bayeux tapestry, is represented in Fig. 21. It is a small one, having only one mast, whereas the largest had three masts, and were able to carry sixty men in armour besides

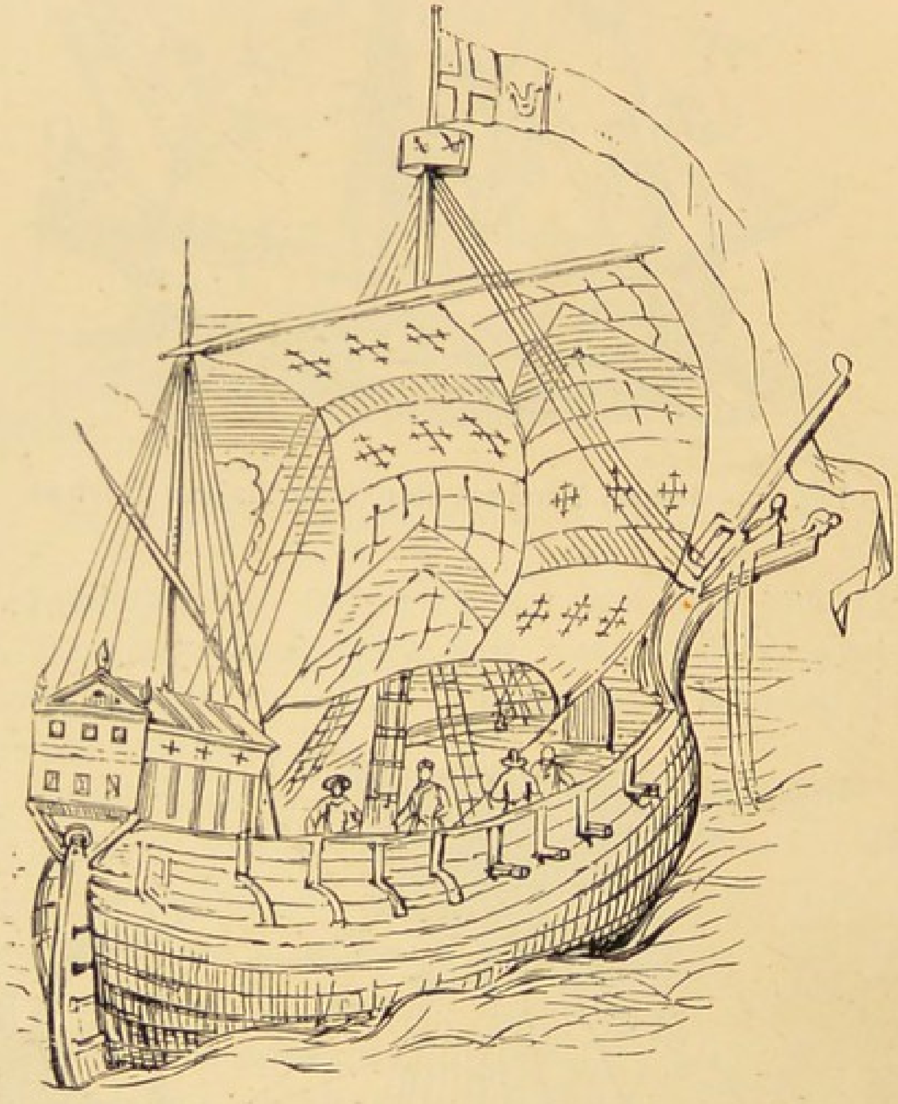


Fig. 22.—Warship, Fifteenth Century

the crew. Richard I. had thirteen of these on his expedition to the Holy Land, besides a hundred smaller ships and fifty galleys.

By the fifteenth century the ships began to approximate towards the type of the eighteenth century, as shown in

Fig. 22, from a MS. in the Cottonian Library at the British Museum. It is said to represent the ship in which Earl Richard sailed to the Holy Land in the reign of Henry IV., and seems to have been a medium-sized warship.

Fig. 23.—The *Harry Grace Dieu*, Sixteenth Century

King Henry VIII. built a ship of 1000 tons called the *Regent*, which was burnt during an engagement, and, to replace it, he built one still larger, the *Harry Grace Dieu*, as represented in the engraving (Fig. 23). But a still finer

vessel seems to have been the *Great Harry*, built by Henry VII. (Fig. 24). Both were four-masted two-deckers, but the earlier ship approximated more to the modern type. The heavy castellated fortresses in the bow and stern are, however, distinguishing mediæval features.

Fig. 24.—Early Sixteenth Century (Henry VII.)

Our next cut (Fig. 25) represents one of the vessels with which John Cabot, sailing from Bristol in 1497, discovered the northern parts of the continent of North America, and it will serve to show the kind of vessels in which Columbus a few years earlier had first crossed the Atlantic Ocean in its widest part.

A great advance is seen in the *Royal Sovereign* (Fig. 26)

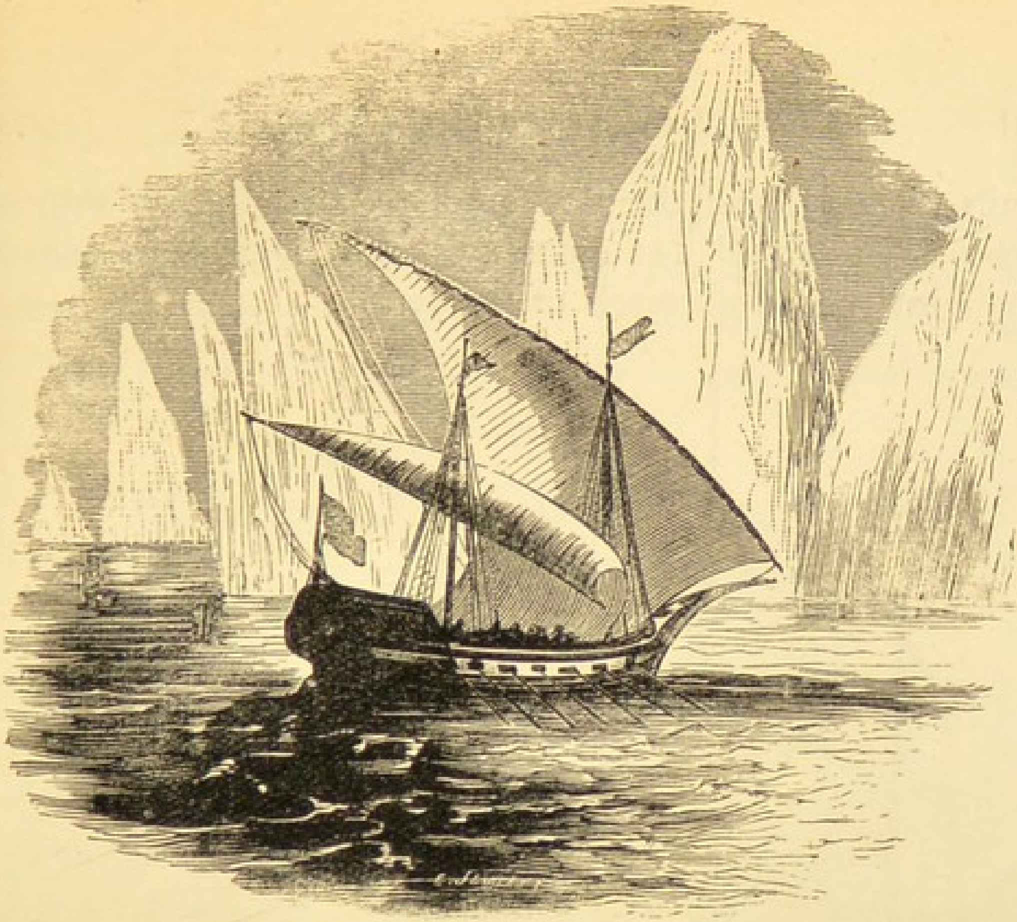


Fig. 25.—One of Cabot's Ships, 1497

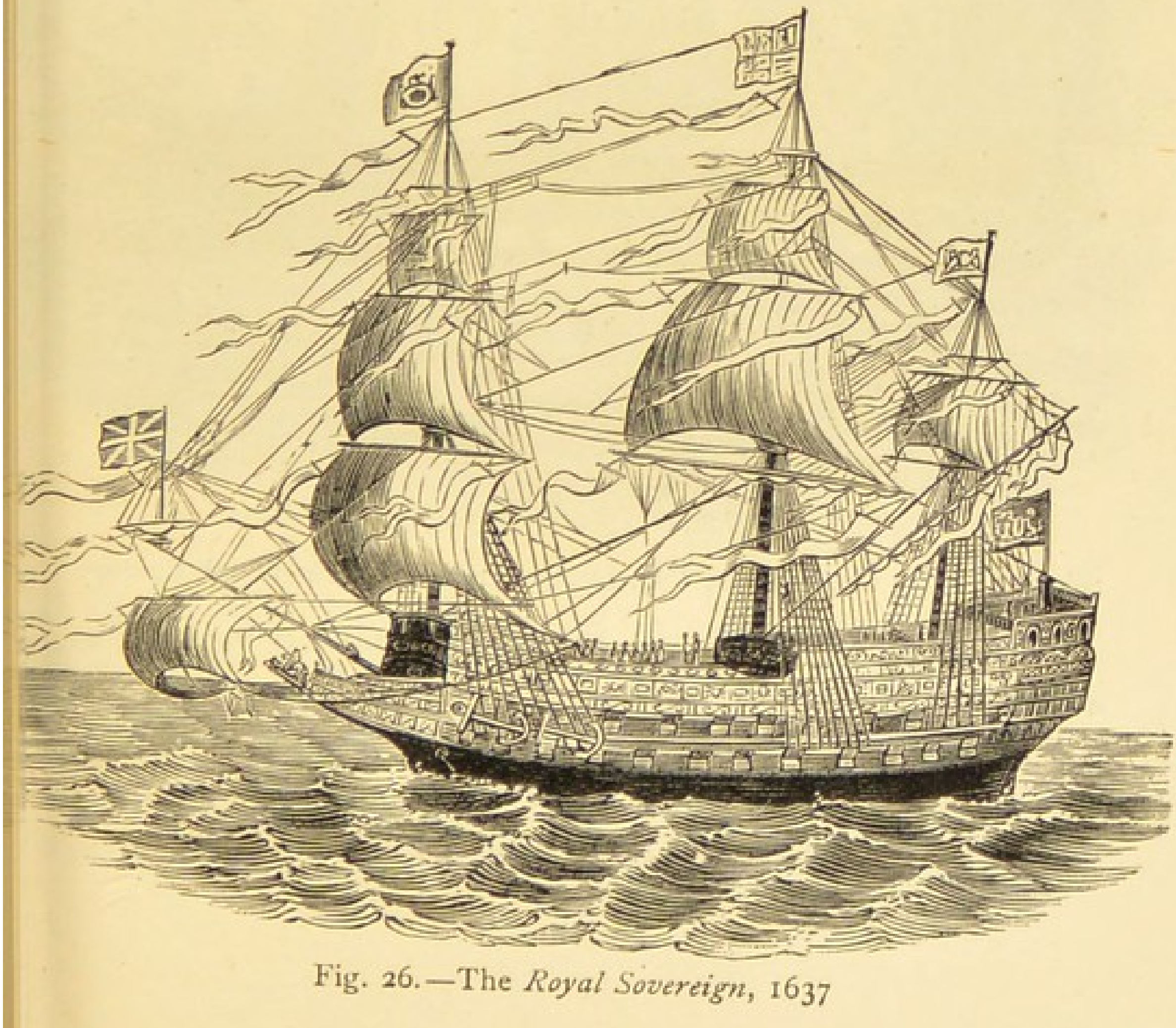


Fig. 26.—The *Royal Sovereign*, 1637

built in 1637, and the first three-decked English ship of war. She carried 112 guns, and must have been one of the most powerful vessels of the period.

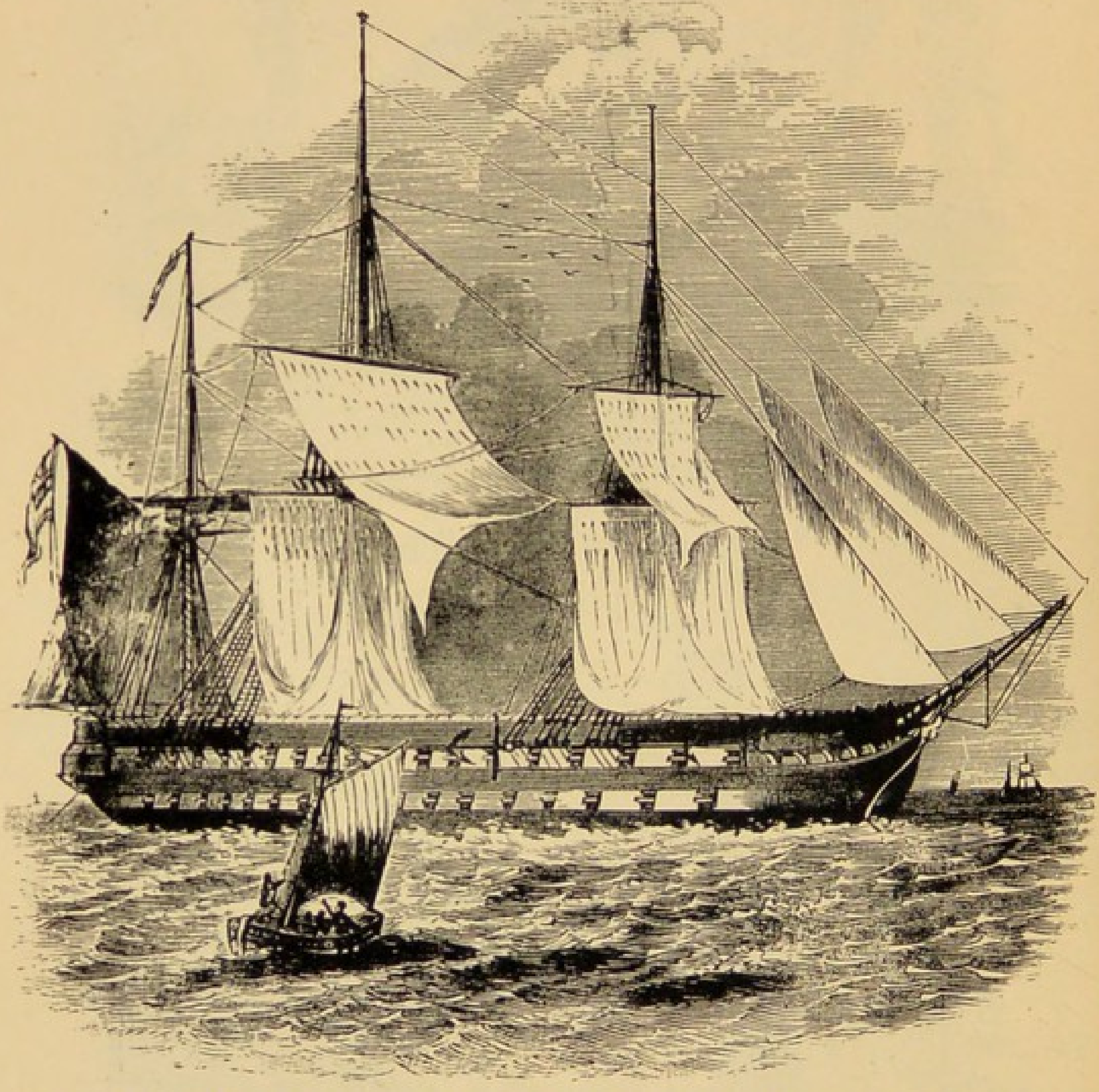


Fig. 27.—The *Collingwood*, Two-Decker, Middle of Nineteenth Century

In contrast with this we have, two hundred years later, a ship of about the same power but probably much longer, the two-decker ship of war, the *Collingwood*, in which we see grace of form, combined with a powerful armament, low and flush decks, and great sailing power (Fig. 27).

The climax of effectiveness in sailing merchant-ships is exhibited by the iron clipper *Tayleur* (Fig. 25), built for the Australian trade in 1853. This vessel carried 4000 tons of cargo; was 250 feet long on deck, and 40 feet beam.

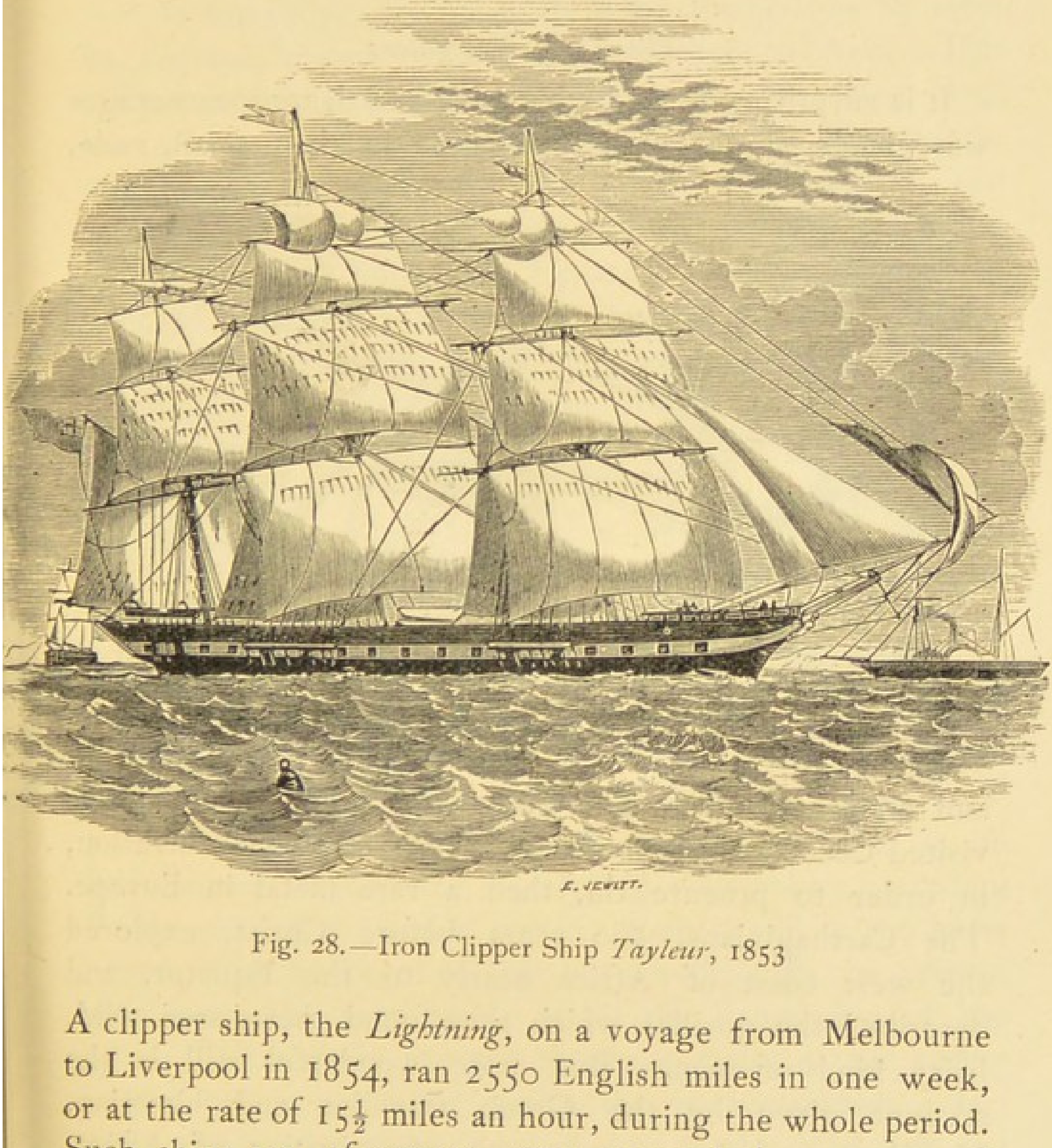


Fig. 28.—Iron Clipper Ship *Tayleur*, 1853

A clipper ship, the *Lightning*, on a voyage from Melbourne to Liverpool in 1854, ran 2550 English miles in one week, or at the rate of $15\frac{1}{2}$ miles an hour, during the whole period. Such ships are, of course, very economical, as compared with steamships, but, owing to calms and contrary winds, their speed is necessarily unequal, though not very much

so in long voyages. The clipper ship, the *Tayleur*, under full sail, and the smaller cut of the China clipper (Fig. 29) afford pictures of grace, beauty, and the effective use of the natural power of wind which can hardly be surpassed.

The Early Navigators

It is surprising to find what long and dangerous voyages were made by the early navigators in their small, rude,

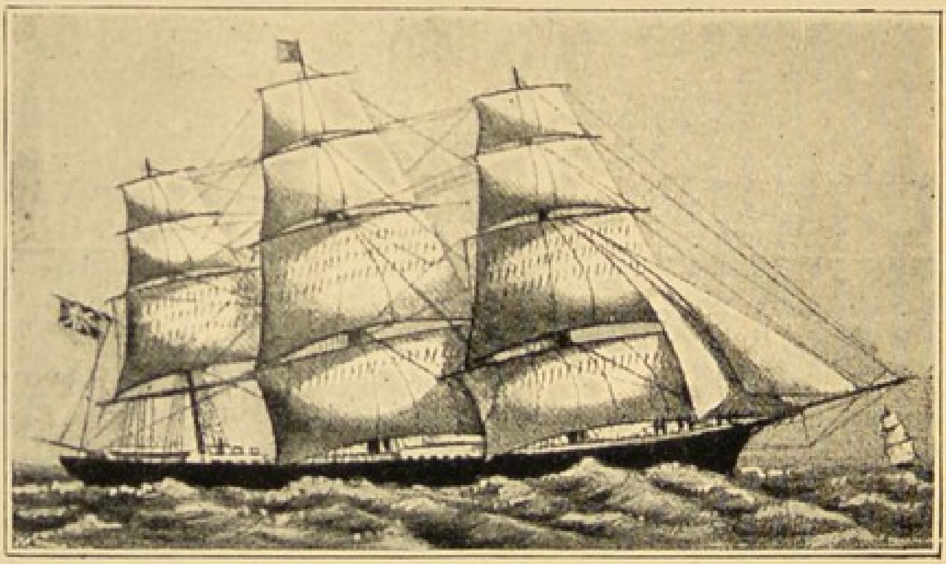


Fig. 29.—A Clipper Ship in the China Trade, 1850

and clumsy vessels. The Phœnicians are known to have visited Cornwall long before the time of Cæsar's invasion, in order to procure tin, then a rare metal in Europe. The Carthaginians, 500 years before Christ, explored the west coast of Africa nearly to the Equator, and described the gorillas which they found there, as a wild, hairy kind of men. But more wonderful still is the account given by the Greek traveller and historian, Herodotus, of the complete circumnavigation of Africa, then called Libya, by Phœnician sailors, under the orders of an Egyptian king, about 616 B.C. This voyage is

usually disbelieved, but there is nothing whatever in it that is incredible, while there is a most interesting piece of internal evidence proving it to be genuine. In Rawlinson's translation of Herodotus the account given by the old historian is as follows:—

"As for Libya, we know it to be washed on all sides by the sea, except where it is attached to Asia. This discovery was first made by Necos, the Egyptian king, who sent to sea a number of ships manned by Phœnicians, with orders to make for the pillars of Hercules, and return to Egypt through them and by the Mediterranean. The Phœnicians took their departure from Egypt by way of the Erythrœan sea, and so sailed into the Southern ocean. When autumn came, they went on shore wherever they might happen to be, and having sown a tract of land with corn, waited until the grain was fit to cut. Having reaped it, they again set sail, and thus it came to pass that two whole years went by, and it was not till the third year that they doubled the pillars of Hercules and made good their voyage home. On their return they declared—I, for my part do not believe them, but perhaps others may—that in sailing around Libya they had the sun upon their right hand. In this way was the extent of Libya discovered."

Now Herodotus was himself a great traveller in all the countries around the Eastern Mediterranean, including Persia and Egypt; and it was no doubt while in the latter country that he heard of this voyage through the priests, who were the repositaries of all the knowledge of the age. He evidently has not the least doubt of the reality of the voyage, and it is certain that so remarkable a fact as a number of ships starting out of the Red Sea and returning by the Mediterranean, and which had happened little more than a century before, would be perfectly well

known and accurately recorded in so highly civilised a country as Egypt. And the fact stated, of the sun being on their right hand when sailing round the extremity of Africa, which Herodotus disbelieved, really proves the truth of the narrative, since it could not possibly have been invented at a time when the earth was held to be a plane. But it would be a most marvellous phenomenon to the sailors, and one on which they would dwell as showing the almost supernatural character of the regions to which they had penetrated. Also, the fact of their taking three years to make the journey would hardly have been invented, since it was not supposed that any land extended so far to the south as to require so long a journey. It is almost certain that some record of this voyage must have been made for the king who ordered it, and there is therefore a possibility of its discovery by excavations in some of the temples or palaces of Egypt.

The next most eventful voyage is that of the Northmen, who in the eleventh century crossed the stormy North Atlantic from Iceland in three separate expeditions, from A.D. 1000 to 1007, the last consisting of 160 men and lasting three years. They undoubtedly visited Newfoundland, Nova Scotia, and Massachusetts, naming the latter Vinland from the abundance of wild vines they found there, and which still characterise the district. It is therefore certain that America was discovered long before the time of Columbus, and it has been held by some writers that he had heard of these old voyages. This, however, seems very unlikely, as he would in that case have sailed to the north-west instead of going southward. His great adventure was quite original, and was founded on the idea of reaching an extension of Asia, not of discovering a new continent.

It was in 1492 that Columbus sailed across the Atlantic

in its very widest part, from Spain to the Bahamas, in three small vessels, two of which were probably of the type of Cabot's ship (Fig. 25) and one somewhat larger; but even this, the *Santa Maria*, was only 100 tons burthen. Of the others the *Pinta* was 50 tons and the *Nina* only 40 tons. The *Santa Maria* having been wrecked, the return voyage was made in the two smaller ships, which found their way safely back to Spain.

While Columbus was making this memorable voyage, the boldest in all human history, Portuguese ships were engaged in discoveries hardly less important and dangerous. In the year 1486 the King of Portugal sent Bartholomew Diaz with two ships to explore the west coast of Africa, as far south as possible. Many expeditions had already been sent on the same route; but the coast beyond the Canary Islands was so stormy and dangerous that it was only after numerous failures that the Cape de Verde Islands and Senegal had been reached, and in 1447 the Rio Grande, in about 11° N. lat. Diaz, however, far exceeded all his predecessors, sailing along the whole west coast, first landing in 26° S. lat., and thence, driven by storms, sailed round the Cape of Good Hope and anchored in Algoa Bay. He was thus the first European to enter the Indian seas from the south. His crew became discontented and alarmed, and he was forced to return, and reached Lisbon safely in December 1487. Ten years later, in 1497, the king sent an expedition of four ships, under Vasco de Gama, to sail round the Cape of Good Hope, or "Cape of Storms" as it was then called, and to reach India. He succeeded against many difficulties, sailed round the Cape, and up the east coast of Africa as far as Melinda, a little north of Mombasa. Here he found a pilot well acquainted with the coast of India, who steered him across the Indian

Ocean in an E.-N.-E. direction to Calicut in about 11° N. lat. There he had to fight with the native ruler, but brought his ship safely back to Lisbon, thus showing the practicability of this new route to all the marvels and riches of the Far East. This great voyage was completed in two years and two months, and its history, adventures, and dangers are described in a fine epic poem by Camoens, "Os Lusiados." The Lusiads have been translated into English no less than six times, the latest version being that by Sir Richard Burton in 1881.

Voyage after voyage was now made to India and the Far East. Malacca was occupied by the Portuguese in 1511, who thus came into contact with the Malay and Arab traders who brought there the rare spices and other products of the Moluccas and New Guinea. America was also being gradually made known by a succession of adventurers. The Amazon was discovered in 1500; the Rio de la Plata in 1508, while Balboa first saw the Pacific Ocean in 1513.

Then came another great navigator, the equal of Columbus himself in boldness and foresight, the Portuguese Ferdinand Magellan. He had served his country in Malacca, and had been seriously wounded in Morocco; but receiving no reward from his own sovereign, he carried his magnificent conception of a voyage round the southern extremity of South America and across the totally unknown Pacific Ocean, to the equally unknown Moluccas, to the Emperor Charles V., who supplied him with five small ships, the largest 130 tons burthen, the smallest only 60 tons, and a total force of 250 men. Leaving Spain in August 1519, he crossed the Atlantic and sailed southward along the cost of Brazil to the La Plata, thence southward to the Straits which bear his name. Some of the Spanish officers mutinied against

him on account of his being a foreigner, but he enforced obedience by landing in Brazil and executing the ringleaders. In the Straits one of his ships deserted, and another had been wrecked before reaching them; but with the three remaining he got safely into the Pacific a little more than a year after starting. He then steered in a west-north-west direction for three months and twenty days without seeing land. But the crews were nearly starved, being reduced to eat leather and drink putrid water. They then came to an island where they found food and water, and shortly after reached the Ladrone Islands. A short voyage from these brought him to the islands of Samar and Zebu in the Philippines, and here (in a small island off Zebu) Magellan was killed, April 27th, 1521. The remainder of the expedition then visited the Moluccas, and at the island of Tidore obtained a quantity of cloves, the first cargo of this valuable spice brought direct to Europe from its place of growth. After many dangers and with great loss of life, the two remaining ships sailed round the Cape of Good Hope, touched at the Cape de Verde Islands, and reached Seville, the 8th of September 1522, having completed the first voyage round the globe in human history.

Thus, within the short space of thirty-five years, with the most inadequate means in ships, and almost wholly without charts or astronomical instruments, all the greatest and most perilous voyages were successfully made. The Atlantic and Pacific Oceans were both crossed in their widest parts, the southern extremities of Africa and America were rounded, the Philippines and Moluccas discovered, and the earth completely circumnavigated. If we take full account of the scanty means and enormous difficulties under which these great results were achieved, we must give to the three men—Columbus, De Gama,

and Magellan—the very highest place among the undaunted and heroic explorers of the world we live upon.

This brief sketch of ocean travel and maritime discovery shows us clearly that, from the very earliest historical periods, and even from prehistoric times, down to the end of the eighteenth century, there had been a slow and continuous improvement in the form and construction of the vessels used for navigating the seas and great oceans, with an absolute identity of principle throughout. The paddles or oars for applying human strength to boats and galleys are the same as they have always been; the rudder or oar for steering has always been used in the same way; while the innumerable kinds of sails, the varying numbers of masts, and modes of rigging, are all alike for the purpose of utilising the winds and storms for driving the various ships or boats in the most effective manner, and all act on exactly the same principle. The grandest man-of-war or full-rigged clipper ship of the middle of the nineteenth century was a direct development, through innumerable small modifications and improvements, from the rudest sailing-boat of the primeval savage.

Then, at the very commencement of the last century, the totally new principle of steam-propulsion began to be used, at first experimentally, and with many failures, on rivers, canals, and lakes, till, about the year 1815, coasting steamships of small size came into pretty general use. These were rapidly improved; but it was not till the year 1838 that the *Great Western*, of 1340 tons and 400 horse-power, made the passage from Bristol to New York in fourteen days, and thus inaugurated the system of ocean steam navigation, which has since developed to such an enormous extent. The average speed then attained was about ten miles an hour, but this speed has now been nearly doubled, and is still increasing.

This is partly due to the use of the screw instead of the paddle-wheel, partly to a great improvement in the construction of steam-engines, but perhaps mainly to the enormous increase in the size of the ships used. But the horse-power needed to attain this high speed has increased in a far higher proportion; and it is only the much greater

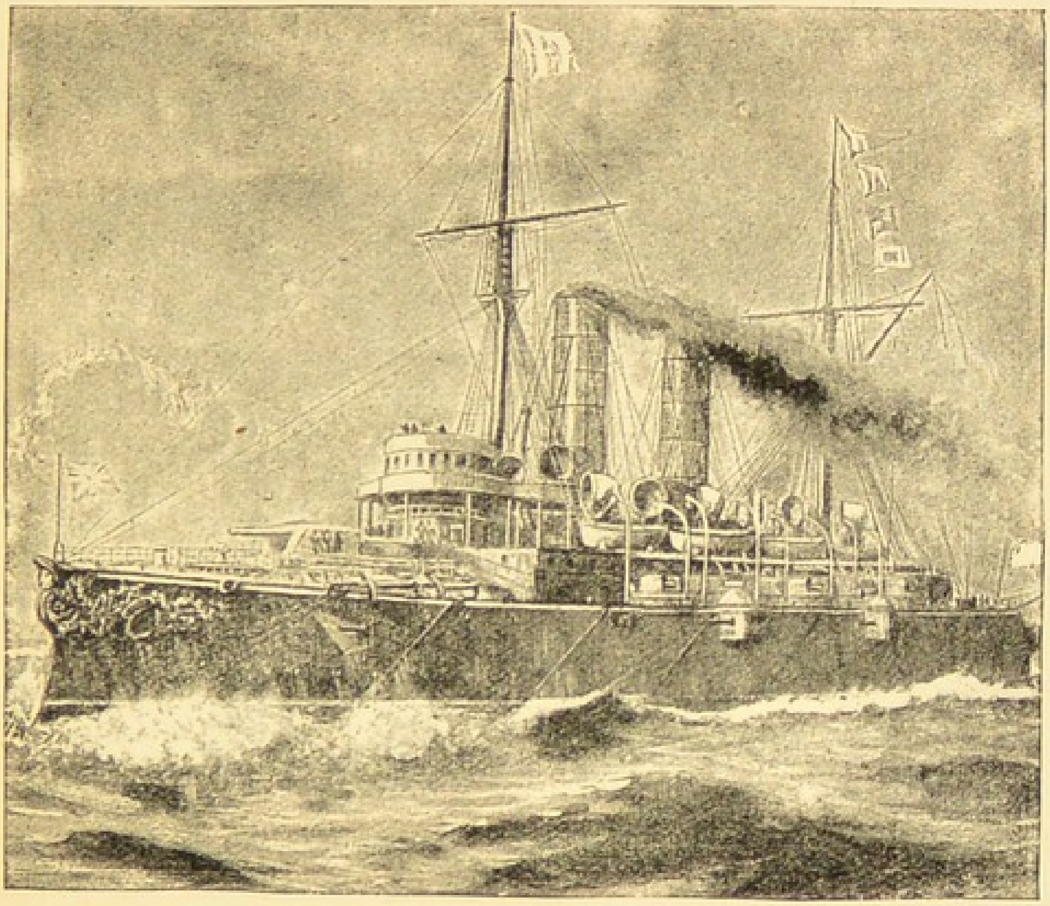


Fig. 30.—A Warship (H.M.S. *Blenheim*), 1900

size and capacity for carrying enormous quantities, both of passengers and goods, that render such high speeds and enormous consumption of coal profitable.

Although the gain in power and speed has been very great, much of the grace and beauty of the old sailing-ships has been lost for ever, as is well seen by comparing the trading and war ships of the middle of the nineteenth century (*see*

Figs. 27-29, pp. 48–50) with the modern steam warship, with its huge armoured towers and smoking funnels (Fig. 30). And as regards the comfort and æsthetical enjoyment of passengers, the steadiness and easy swaying motion of the sailing-ship, the superb beauty of its swelling canvas towering aloft against the sky, with the exquisite curves of its surfaces, and of every line and rope in its complex

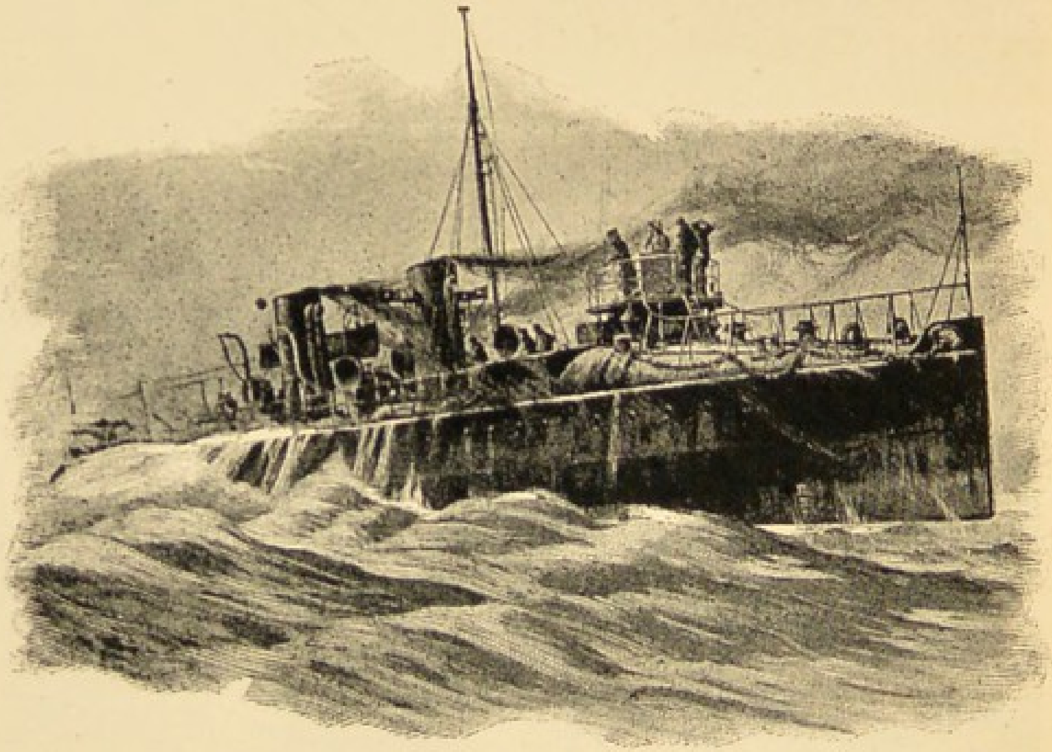


Fig. 31.—A Torpedo-boat, 1900

rigging, were most delightful as compared with the painful vibration of the steam-ship when driven through the waves and against the wind, its jerky motions, its frequent pall of smoke, and its noisome smell of hot oil from the engines. To the traveller for health or pleasure, these more than balance the advantages of greater speed. It is a question also whether the increase of speed has not introduced more elements of danger than of safety.

The latest great advance in steam-navigation is the

invention of the steam-turbine, a very simple and economical form of engine, and the use of a number of screws revolving at high velocities. Some of the small torpedo-boats and torpedo-destroyers built in this way have attained a speed of from thirty to forty miles an hour, and it is possible that even higher velocities may be reached. Many new forms of vessel, such as the cigar-shaped and the roller-boats, have not been adequately tried; and there are other suggested forms, by means of which greater steadiness and speed may yet be obtained.

But custom and prejudice are all in favour of the old forms, and a single failure of any new departure is regarded as final, although that failure may be wholly due to the details rather than to the principle of the new type.

Concluding Remarks on Advance in Locomotion

We see, then, that during the nineteenth century three distinct modes of locomotion have been originated and brought to a high degree of perfection. They are altogether different in principle from anything which had gone before. Up to the very times of men now living, all our locomotion was on the same old lines which had been used for thousands of years. It had been improved in details, but without any alteration of method, and without any very great increase of efficiency. The principles on which our present methods rest are new; they already far surpass anything that could be effected by the older methods; with wonderful rapidity they have spread over the whole world, and they have in many ways modified the habits, and even the modes of speech, of all civilised peoples.

This vast change in the methods of human locomotion,

already so ubiquitous that to the younger generation their absence rather than their presence is considered remarkable, has been almost wholly effected within the writer's memory, and is of itself sufficiently striking and important to justify the appellation of "The Wonderful Century" to that period which witnessed its rise, its progress, and its maturity of development.

CHAPTER III

LABOUR-SAVING MACHINERY

"Wonderful chair! Wonderful houses! Wonderful people!
Whirr! whirr! all by wheels! Whizz! whizz! all by steam."
EOTHEN.

"Work—work—work
Till the brain begins to swim;
Work—work—work
Till the eyes are heavy and dim!
Seam and gusset and band,
Band and gusset and seam,
Till over the buttons I fall asleep,
And sew them on in a dream."
HOOD.

THE invention and partial development of much of our modern machinery dates from the last century, and our most advanced appliances for the manufacture of the various textile fabrics and hardware are mostly improvements of, or developments from, the older machines. These, taken in connection with the great improvements in steam-engines, have multiplied many times over the efficiency of human labour, but do not otherwise specially interest us here. There are, however, a few inventions which have the character of quite new departures, since not only do they greatly diminish labour, but they perform, by mechanical contrivances, operations which had been supposed to be beyond the power of machinery to execute. The more prominent of these are the sewing-machine, the typewriter, and the combined reaping, thrashing, and winnowing machine, of which a brief account will be given.

The sewing-machine, now so common, exercised the ingenuity of mechanicians for a long period before it arrived at sufficient perfection to be suitable for general use. The earlier machines were for embroidering only; then, about 1790, one was made for stitching shoes and other leather work, but it does not seem to have come into general use. A crocheting machine was patented in 1834; somewhat later, one for rough basting; but it was not till 1846 that the first effective lock-stitch sewing-machine was made by Elias Howe, of Cambridge, Massachusetts. Henceforth sewing-machines were rapidly improved and adapted to every variety of work; but the difficulty of the problem to be solved is shown by the unusually long process of gradual development, much of the mechanical talent of both hemispheres being occupied for nearly a century before the various machines so familiar to-day were perfected. There are now special machines for making button-holes and for sewing on buttons, for carpet-sewing, for pattern-sewing, for leather-work, and for the special operations required in the making and repairing of shoes. Boot and shoemaking by machinery, in large factories, has entirely grown up since the sewing-machine was proved to be adapted for almost every kind of sewing-work. As a result machine-made boots and shoes are

Fig. 32.—The Hand Sewing of 1800

very cheap, but they are usually of inferior quality to the old hand-made articles; and first-class work is quite as dear as it was fifty or sixty years ago, or even dearer.

Fig. 33.—The Sewing Machine of 1900

The typewriter is a still later invention, and though perhaps less difficult than the sewing-machine, yet it involves more complex motions and adjustments, and the perfection it has so quickly attained is very remarkable. If we consider that about sixty separate types, including small letters, capitals, spaces, stops, etc., have to be so arranged and so connected as to be brought in any order whatever to a definite position, so as to form the successive letters and spaces in lines of printed characters, and then, being properly inked, must be brought into contact with the paper so as to produce a clear impression, and that all the motions of the machinery required must be the result of a single pressure on a key for each letter, following one another as rapidly as possible, we shall have some idea of the difficulties which have had to be overcome. Yet, so great are the resources of modern mechanism,

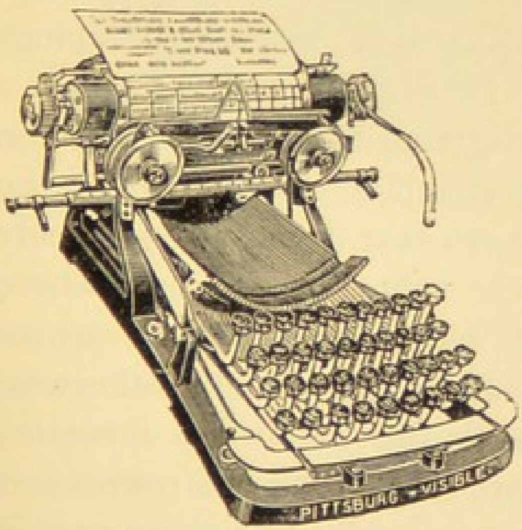


Fig. 34.—Typewriter

and the ingenuity of our mechanists, that the required result has been attained in many different ways, so that we may now choose between half-a-dozen forms of type-writers, no one of which seems to be very markedly superior to the rest.

More important, perhaps, to mankind generally, are the harvesting machines, which render it possible to utilise one or two fine days to secure a harvest. Reaping-machines are of great antiquity, since Pliny the elder describes one. He says: "In the extensive fields in the lowlands of Gaul vans of large size, with projecting teeth on the edge, are driven on two wheels through the standing corn by an ox yoked in a reverse position. In this manner the ears are torn off and fall into the van." Nothing seems to be known of any further use of such machines till the early part of the nineteenth century. In 1826 Mr Patrick Bell constructed a machine which was so efficient that it long continued in use in Scotland, and the chief features of which are retained in many of the reaping-machines still in use. In America Hussey and M'Cormick patented reaping-machines in 1833 and 1834. In 1843 Mr John Ridley, a miller of Durham, who had emigrated to South Australia in 1840, invented a machine for stripping off the ears of the wheat and separating the grain, so that it was at once ready for market. This was of great value in a country where labour was very scarce, and by its means large quantities of wheat were harvested which would otherwise have been lost. This machine, improved by the inventor, was of such value to the colony, that in 1845 a testimonial was presented to him by the Agricultural Society, and in 1861, after he had returned to England, a silver candelabrum, made in Adelaide, was sent to him by the farmers and leading colonists.

In England, where the straw is valuable, most improved

machines cut the straw low down, bind it into sheaves, and leave it on the ground ready to be carted home, as in Howard's reaper and binder.

In America a harvesting machine has been brought to such perfection that it not only cuts the crop low down so as to secure the straw, but threshes it, winnows it, and delivers it into sacks ready for the granary or the market at one operation. This machine, with two men, will, in

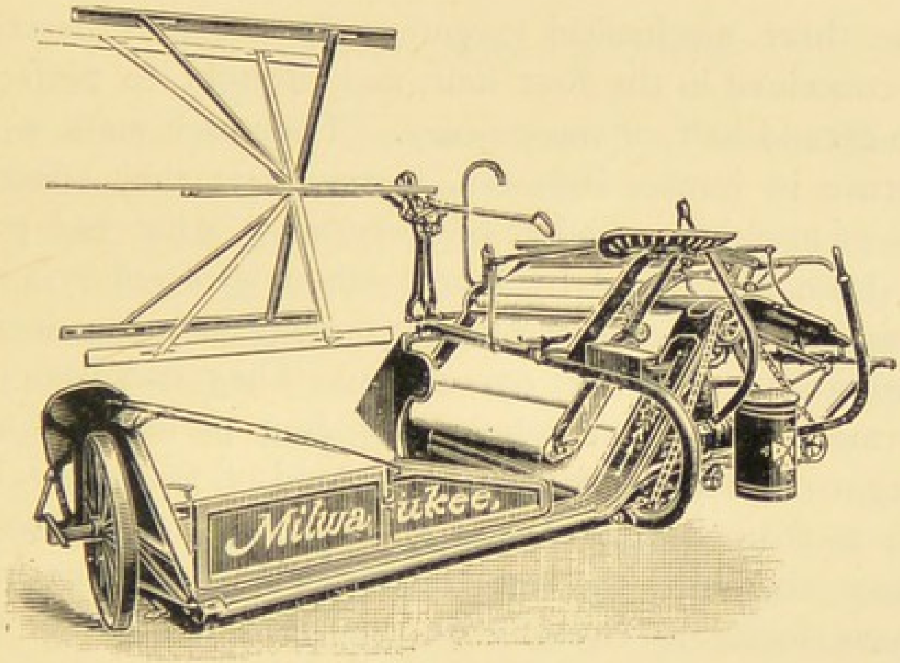


Fig. 35.—A Typical American Harvesting-Machine, embodying the Latest Improvements

one fine day, secure the crop from ten or fifteen acres, with a minimum of labour. In the great wheat-fields of California and Australia, with an almost uniformly dry climate at harvest time, it is this saving of labour which is the chief consideration; but in our treacherous climate, where a few days' delay may mean the partial or complete ruin of the crop, such machines will be doubly valuable by enabling farmers to utilise to the utmost every fine day after the grain is ripe. I had the pleasure of seeing one

of the first of these machines at work in California in 1887. It was propelled by sixteen small mules harnessed behind, so as not to be in the way; but steam power is now used. Considering what it effected, it was wonderfully light, compact, and simple; and when agriculture is treated as a work of national importance, such machines will render us, to a considerable extent, independent of the weather, and will therefore become a necessity.

The three mechanical inventions here briefly described were conceived in the first half, and brought to perfection in the second half, of the century. They each mark a new departure in human industry, inasmuch as they effect, by means of machinery, and at one operation, what had previously been performed by human labour directed by a hand or arm rendered skilful by long practice, and sometimes requiring several distinct operations. They had been thus performed during the whole preceding period of human history, or so long as the particular kind of work had been done; so that though of less general use and of less importance, they have the same distinguishing features which we have found to characterise our new methods of locomotion.

There are, of course, innumerable other remarkable mechanical inventions of the century in almost every department of industry—such as the Jacquard loom for pattern-weaving, steel pens, revolvers and machine-guns, iron ships, screw-propellers, etc.; while machinery has been extensively applied to watch-making, screw-cutting, nail-making, printing, and a hundred other purposes. But none of these are of very high importance in themselves, or possess the special characteristics of being new and quite distinct departures from what has been done before, and they cannot, therefore, rank individually among those

greater discoveries which pre-eminently distinguish the nineteenth century.

But besides these entirely new machines there are several other developments in the use of the various mechanical powers which, though less generally known, are, at least, equally, and, perhaps, even more important. Some of these will now be considered.

Old and New Sources of Power

The natural sources of power known to and utilised by the ancients were two only, wind and running water. The use of both goes back to an unknown antiquity, but they did not become general till towards the end of our first millennium. Water-mills were known to the Romans in the time of Julius Cæsar, and they were used either for raising water for irrigation, or for grinding corn. But, owing to the abundance of slaves and cattle, their use was comparatively rare. In the time of the Emperor Constantine slaves were condemned to the mills as a punishment, and about the same period it is recorded that there were three hundred cattle-mills in Rome. About A.D. 400 public mills were established there, and were worked by the abundant waters of the great aqueducts. It seems probable, indeed, that water-mills were more common among the free Germanic and Celtic peoples than among the slave-owning Romans, since they were commonly used in Britain before the Norman Conquest, and their main features continued unchanged down to the beginning of the nineteenth century. In private houses, monasteries, etc., hand or cattle-mills continued in use till the fifteenth century, and perhaps later.

Wind-mills seem to have been a somewhat later inven-

tion, and their introduction into Europe was popularly believed to have been due to the returning crusaders, but this is probably a myth, as such mills are almost or quite unknown in the East; but they were, perhaps, then used in Germany, and may have been seen by some of the wandering knights. One of the earliest mentions of them is in a deed in 1105, allowing a convent in France to erect both water-mills and wind-mills; and they are also mentioned about the same period in English charters.* They were, however, still rather scarce, and it was not till the fourteenth or fifteenth centuries that they became common throughout Europe.

From the earliest times, also, the use of millstones, an upper one rotating upon a fixed lower one, remained practically unchanged, and have furnished the languages of all civilised peoples with characteristic figures of speech, while the geological term *millstone-grit*, will long remain after its special use is forgotten. In the early years of the century we are dealing with, almost every town and important village had its water or wind-mills, where we could see the old upper and nether millstones at work, and realise the numerous references to them and to the miller's craft in our old writers and poets. But with the growth of railways, and of big cities, and of the importation of foreign corn, steam-mills at the great seaports took the place of the picturesque old water and wind-mills scattered through the rural districts; and with competition, and the foolish preference for flour of extreme whiteness, a succession of steel rollers drove out the old millstones, which, with the mills they worked, will soon become things of the past. It is not impossible, however, that they may some day come back to us. For when, in a more rational

* See Beckmann's "History of Inventions" for a long discussion on this interesting subject.

system of society, our population becomes more evenly distributed over the land, it may again become advantageous for each community to grind its own corn by means of water or wind power, and not only enjoy pure bread made of freshly-ground corn—a luxury now almost unknown—but utilise the simple, natural forces which we now neglect solely because concentration and steam are better suited to the accumulation of wealth by great capitalists, though positively injurious to the rest of the community.

Indications are not wanting, however, that steam itself may before long be superseded by simpler and less costly means of obtaining mechanical power. Such are the various gas and petroleum engines now largely used for domestic work, in small workshops, and for the propulsion of motor-cars and cycles. In these we have a completely new departure, since they make use of the explosive force of gas or petroleum vapour mixed with air instead of the expansive force of steam produced by coal in a huge furnace. Furnace and boiler are both dispensed with, resulting in very great reduction of bulk and economy of working. There are probably a hundred thousand engines of this nature used in hotels, country houses, workshops, and various domestic industries, and their use is likely to increase as their advantages become more widely known.

Of late years the method of transmitting power by means of compressed air or water has been frequently used, and is found to be both economical and effective. In this way the boring machines in the Mount Cenis tunnel were worked by compressed air pumped in by water-power. At Geneva, water is pumped up from the Rhone by turbines to a high-level reservoir, and there distributed by pipes, not only for domestic use, but as a motive power

in printing-offices and numerous workshops, especially those of the watch and jewellery industries.

As in most temperate regions there is an abundance of water and wind-power now almost wholly wasted, it seems quite certain that the time will come when these simple natural forces will be more fully utilised, and nearly the whole of the necessary mechanical work be done by means of them. In every part of the country not only could motive power be distributed, but also electric light and heat, as well as an abundance of pure water. Coal would then be of little or no importance to us, and the hideous smoke-demon would be finally destroyed.

In Paris compressed air has been taken seven miles for the purposes of an electric light installation near the Madeleine, for refrigerating purposes, and for operating over 30,000 pneumatic clocks in hotels and private houses; and a similar supply has been long in use in Birmingham for carrying motive power to numerous small workshops. But the most interesting application of air-pressure is in what is known as the Pneumatic Dispatch used for distributing telegrams from the central office in London to the various district offices, and the same system is used in Paris and some other Continental cities. Lead pipes 2¼ inches diameter are laid between the offices, and the telegrams are packed in small tubular carriers, which are driven along either by compressed air or by suction. The carriers travel at the rate of about 1000 yards in a minute, and as a continued stream of them can be kept going, the economy of time and labour is very great. There are now about forty miles of such tubes in London alone.

But although both water and air are economical for transmission of power for moderate distances and on a small scale, yet the loss of power by leakage, friction, etc., becomes of importance in larger works and for longer

distances; and for such cases the transmission of power by electricity is much more economical, and in various ways more advantageous. In many parts of Switzerland, in the Jura, and in North America, the power derived from rivers and waterfalls is being utilised to work many kinds of machinery, often ten miles, and sometimes more than a hundred miles from the source of the power.

The most gigantic of all these works are those of the Cataract Construction Company at Niagara. The water is taken from the Niagara river, a mile and a quarter above the falls, by a canal 12 feet deep, and carrying sufficient water to produce 100,000 horse-power. This canal is 1700 feet long, with ten flood-gates near the end, by which water can be delivered to the wheel-pit, which is 140 feet long and 178 feet deep. The outlet at the bottom of this huge pit is connected with a main tunnel more than a mile long, terminating in the Niagara river below the falls, and near the new suspension bridge. This tunnel is to carry away the water after it has done its work on the turbines. This tunnel has a slope such that when nearly full the water will have a velocity of twenty miles an hour. It is over 18 feet wide, with a maximum height of 21 feet. Owing to the rock being a friable shale, the tunnel had to be lined with timber and brickwork to a total thickness of 3 to 4 feet. This enormous tunnel, whose sole but essential purpose is to afford a free escape for the waste water, took three years to build.

The mode of utilising the water-power is simple, yet involving works of great ingenuity and difficulty. In the wheel-pit are ten vertical steel tubes, each 7½ feet in diameter, down which the water sinks, and works a turbine wheel of 5000 horse-power placed a few feet from the base of each tube. From this horizontal wheel rises a tubular steel shaft, 140 feet long, which makes 250 revolutions

a minute, and works the electrical generator in the power-house above. The electric current thus produced is conveyed by wires or cables to various factories at Buffalo and other localities, where, by means of suitable dynamos, it will be re-converted into mechanical power. Buffalo, an important port and manufacturing centre, is about twenty miles distant, but it is believed that power will soon be distributed to places much farther away.

The various modes of transmitting mechanical power from its place of origin to considerable distances—and by electricity probably to any useful distance—is one of those perfectly new developments which characterise the nineteenth century, and which are sure to have a greatly extended application in the future. When society becomes rationally organised, and the health and well-being of every human being are considered to be of greater importance than the wealth and luxury of the few, the simpler modes of utilising natural forces will be applied to innumerable household purposes, rendering a refined life with ample leisure possible for all.

Power from Liquid Air

There is one other source of power which seems likely to come into use in the not distant future, and which in its wide-reaching effects may possibly prove to be one of the most important. In our Chapter VIII. it is shown by what simple arrangements, and with comparatively very little expenditure of energy, we can produce liquid air having a temperature of -300° Fahrenheit. This liquid can, in properly constructed vessels, be kept for days with very little loss, and it has already been applied by American engineers to work small motors for various purposes. By

means of small spiral copper tubes the air is brought gradually to the cylinder of the air-engine, where it exerts its full expansive force of about 12,000 pounds per square inch. On a large scale it is stated that it can be produced at a cost of less than a penny a gallon. The advantage of using it for motors and other domestic purposes would be very great, especially on account of its perfect cleanliness, requiring no fire of any kind, the absence of all smell, its perfect portability, and the simplicity of the apparatus required to make and use it, so that it could be made as required by a small wind or water-engine. This may yet prove to be one of the most useful and novel inventions of the nineteenth century.

CHAPTER IV

THE CONVEYANCE OF THOUGHT

"I sent a message to my dear—
A thousand leagues and more to Her—
The dumb sea-levels thrilled to hear,
And Lost Atlantis bore to Her."

KIPLING.

THE history of the progress of communication between persons at a distance from each other has gone through three stages which are radically distinct. At first it was

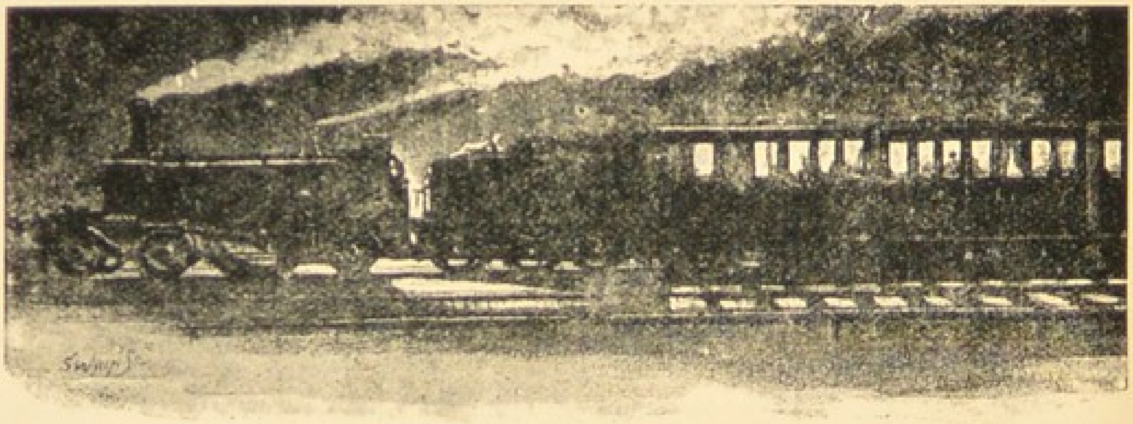


Fig. 36.—A Mail Train, 1900

dependent on the voice or on gestures, and a message to a friend (or enemy) at a distance could only be sent through a messenger, and was liable to distortion through failure of memory. The heralds and ambassadors of early times thus communicated orders from kings to their subjects, or conveyed messages from one king to another. Then came the invention of writing, and a new era of

communication began. Letters were capable of conveying secret information and copious details, which could not be safely entrusted to the uncertain memory of an intermediary; and a single messenger could convey a large number of letters to various persons on the way to his ultimate destination. Henceforth the progress of communications was bound up with that of locomotion, and, as civilisation advanced, arrangements were made for the conveyance of letters at a comparatively small cost. A post-office for the public service was first established by some Continental merchants in the fourteenth century; but it was not till the time of Charles I. that anything of the kind was to be found in England, and then it was mainly for the purpose of keeping up a communication between London and Edinburgh, and the intervening large towns, for Government purposes. It was, however, the starting-point of our existing postal system, which has been gradually extended under the direction of the King's Postmaster-General, and has continued to be a Government monopoly to our day. The letters were carried on horseback till 1783, when mail coaches were first introduced; and these led to a great improvement in our main roads, and the extension of the postal service to every town and village in the kingdom.

But even with good roads and mail coaches, the actual time taken in the despatch of a letter to a distant place was little, if any, less than had been possible from the earliest times, by means of relays of runners on foot or by swift horsemen. The improvement consisted in the regularity and economy of the postal service. The introduction of railways and steamships enabled much greater speed to be secured; but the greatest and most beneficial improvement in the administration of the Post-Office was that inaugurated by Rowland Hill in 1840. The rule,

then first introduced, of a uniform charge irrespective of distance, is one of those entirely new departures so many of which characterise our century, and which not only produce immediate beneficial effects, but are the starting-points of various unforeseen developments. It

Fig. 37.—An English Mail-Coach in 1800

was founded, in this case, on a careful estimate of the various items which make up the cost of the carriage and delivery of each letter, and it was shown that the actual conveyance, even for the greatest distances, was the smallest part of the cost when the number of letters is large, the chief items of expense being the office work—the sorting, stamping, packing, etc.—and the final delivery,

all of which are quite independent of the distance the letter is carried. The old system, therefore, of increasing the charge for postage in proportion to distance was altogether unreasonable, because the cost of conveyance was hardly perceptibly increased; and if the Post-Office was considered to be a public service for the public benefit only, the people had a right to demand that they should pay only in proportion to the cost. Yet the principle was not at first, and is not even now, fully carried out. For thirty years, from 1840 to 1871, the postage was increased equally with each successive increment of weight, the half-ounce letter being a penny, while one of two ounces was fourpence. But as the chief items of expense — the office-work and delivery — were the same, or nearly the same, in both cases, the double or quadruple charge was entirely opposed to the principle on which the uniform rate was originally founded. Accordingly, in 1871, when an ounce letter was first carried for a penny, and recently, when the weight was increased to four ounces, each additional two ounces was charged a halfpenny. This accepted and common-sense principle, however, has not yet been applied to the charges of the Postal Union, so that a letter which is a fraction over the half-ounce is charged fivepence, or double, and one over an ounce and a half tenpence, or four times that of the half-ounce letter, although an extra halfpenny would probably cover the extra cost of the service in both cases.

The same inability of the official mind to carry out an admitted principle is seen also in the case of Postal Orders. The cost to the Post-Office of receiving and paying money is exactly the same whether the amount is eighteen-pence or fifteen shillings, and there is neither justice nor common-sense in charging three times as much in the latter case. There is no risk, because the money

is paid in advance; and as the amounts taken in and paid out for Postal Orders must be approximately equal, it is difficult to see what justification there is for making any difference in charge. The same objection applies to Money Orders; and as there is doubtless a certain percentage of both which, from various causes, are never presented for payment, the profit to the Post-Office must be greater in case of the higher amounts, which is another reason why these should not be exceptionally taxed. When the railways are taken over by the State, to be worked for the good of the community only, the principle will admit of great extension, each increment of distance being charged at a lower rate, just as is each increment of weight in our inland letters.

Signal Telegraphs

The transmission of important information by signals over long distances and with extreme rapidity, has been used in all ages, chiefly by means of signal fires or beacons. Macaulay picturesquely describes those which announced the approach of the Spanish Armada.

> "For swift to east and swift to west the ghastly war-flame spread,
> High on St Michael's Mount it shone: it shone on Beachy Head.
> Far on the deep the Spaniard saw, along each southern shire,
> Cape beyond cape, in endless range, those twinkling points of fire."

In order to send connected messages, the Semaphore was invented in the eighteenth century and was much used, both by the English and French Governments. It consisted of a series of towers on hill-tops from five to ten miles apart. On the top of these towers there were six movable shutters, so arranged in frames that they could be opened in any combination, giving a large number of signals which were interpreted by means of a code, as

in the case of signalling by flags at sea. In 1794 the Admiralty possessed three lines of signal towers between London and Deal, Portsmouth and Plymouth, the signallers at each station instantly repeating what they saw, and this was done so rapidly that a message to Deal or Portsmouth could be sent in a few minutes. In 1816, movable arms, something like modern railway signals, were substituted, and short messages were sent from London to Portsmouth in a single minute. They continued in use till 1847, when the more certain and rapid electric telegraph came into use.

Electric Telegraphs

The third stage in the means of communication, when by means of electric signals it was rendered independent

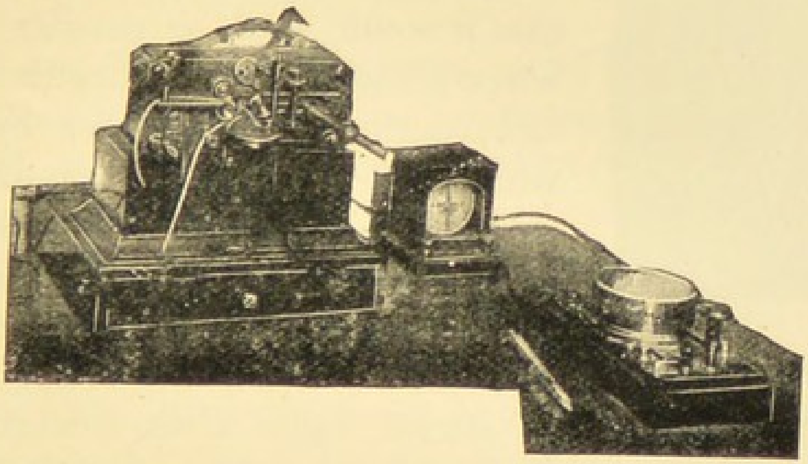


Fig. 38.—Telegraph Instrument

of locomotion, is that which has especially distinguished the nineteenth century. The electric telegraph serves us as a new sense, enabling us to communicate with friends at the other side of the globe almost as rapidly and as easily as if they were in different parts of the same town. The means of communication we now use daily would

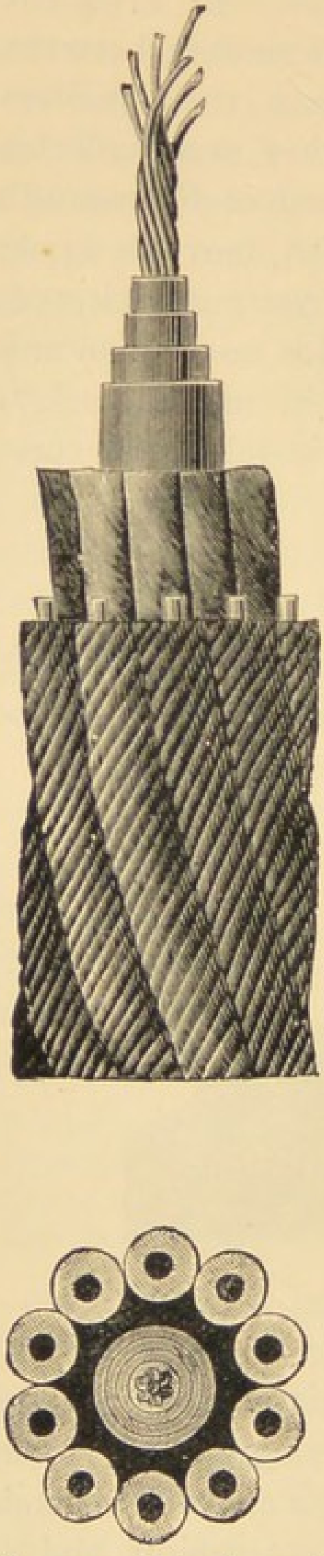


Fig. 39.—The Second Atlantic Cable

have been wholly inconceivable to our ancestors a hundred years ago.

About the middle of the eighteenth century it was perceived by a few students of electricity that it afforded a means of communication at a distance; but it was not till the year 1837 that the efforts of many simultaneous workers overcame the numerous practical difficulties, and the first electric telegraph was established. Its utility was so great, especially in the working of the railways then being rapidly extended over the kingdom, that it soon came into general use; but hardly anyone at first thought that it would ever be possible to lay wires across the ocean depths to distant continents. Yet, step by step, with wonderful rapidity, even this was accomplished. The first submarine line was laid from Dover to Calais in 1851; and only five years afterwards, in 1856, a company was formed to lay an electric cable across the Atlantic. This cable, 2500 miles long, and weighing a ton per mile, was successfully laid, in 1858, from Ireland to Newfoundland; but owing to the weakness of the electric current, and perhaps to imperfections in the cable, it soon became useless, and had to be abandoned. After eight years more of invention and experiment, another cable was successfully

laid in 1866; and there are now no less than fourteen lines across the Atlantic, while all the other oceans have been electrically bridged, so that messages can be sent to almost any part of the globe at a speed which far surpasses the imaginary power of Shakespeare's goblin Puck, who boasted that he could "put a girdle round about the earth in forty minutes." We are now able to receive accounts of great events almost while they are happening on the other side of the globe; and, owing to difference of longitude, we sometimes can hear of an event apparently before it has happened. If some great official were to die at Calcutta at sunset, we should receive the news soon after noon on the same day.

The Telephone

As a result of the numerous experimental researches necessitated for the continuous improvement of the electric telegraph, the telephone was invented, an even more marvellous and unexpected discovery. By it, the human voice, in all its countless modifications of quality and musical tone, and its most complex modulations during speech, is so reproduced at a distance that a speaker or singer can be distinctly heard and understood hundreds of miles away. This is not an actual transmission of the voice, as in the case of a speaking-tube, but a true reproduction by means of two vibrating discs, the one set in motion by the speaker, while the electric current causes identical vibrations in the similar disc at the end of the line, and these vibrations reproduce the exact tones of the voice so as to be perfectly intelligible. At first telephones could only be worked successfully for short distances, but by continuous improvements the dis-

Fig. 40.—Brighton

tance has been steadily increased, so that in America there is a telephone line now in operation between New York and Chicago, cities about a thousand miles apart.

Those who have read Mr Bellamy's wonderful story, "Looking Backward," will remember the concerts continually going on day and night, with telephonic connections to every house, so that every one could listen to the very best obtainable music at will. But few persons are aware that a somewhat similar use of the telephone is actually in operation at Buda-Pesth in the form of a telephonic newspaper. At certain fixed hours throughout the day a good reader is employed to send definite classes of news along the wires which are laid to subscribers' houses and offices, so that each person is able to hear the particular items he desires, without the delay of its being printed and circulated in successive editions of a newspaper. It is stated that the news is supplied to subscribers in this way at little more than the cost of a daily newspaper, and that it is a complete success.

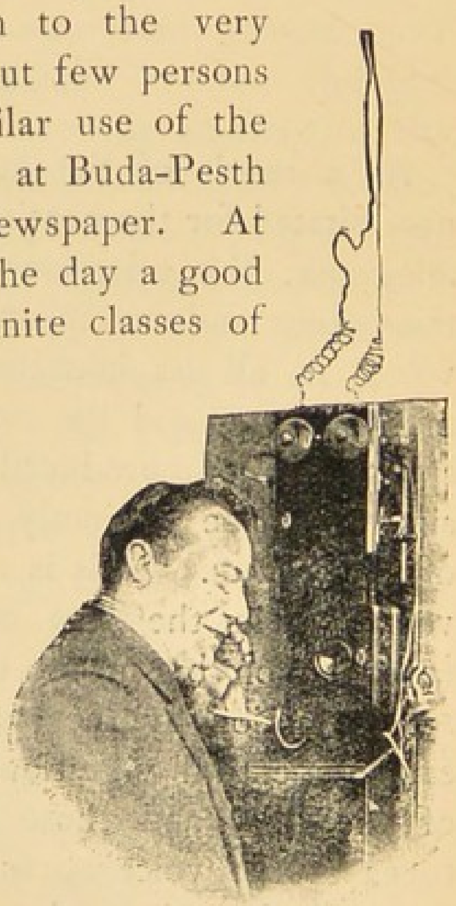


Fig. 41.—London

I have recently obtained information through a friend that this interesting application of the telephone was still in existence in the last year of the nineteenth century.

Wireless Telegraphy

Since the first edition of this volume was written, a new mode of applying electricity for signalling purposes has been discovered, and brought into use, that seems to admit of endless and very marvellous developments. It has long been known that electric currents, under certain conditions, produce waves which spread in all directions from the conducting wires, just as do the sound waves in air, and are able to start currents in other electric circuits quite disconnected with them. This is especially the case with alternating currents or oscillations, the properties of which were studied by Hertz in 1888, and are therefore often spoken of as Hertzian waves. Various modes of detecting these waves have been used by different experimenters, and it has been found possible to transmit messages for considerable distances between unconnected places. Mr W. H. Preece informs us that in 1892 messages were thus sent across a portion of the Bristol Channel, 3½ miles wide. Again, when the electric cable between Oban and the Isle of Mull broke down in 1895, communication was established across this space of about 7 miles by setting up long parallel lines of wires along the opposite shores, each of which would, under the influence of strong alternating currents, send induction waves of sufficient power to give signals in the opposite circuit.

In July 1896, a young Italian electrician, Mr Marconi, brought to England a new method of telegraphing without connecting wires, by the use of very rapidly alternating

currents and a special receiver of extreme delicacy, by which communication is rendered much easier and more certain. This receiver is in principle the same as the coherer of Professor Oliver Lodge, consisting of metallic filings in a tube, which are, at first, insulators, but which are very sensitive to the influence of the Hertzian waves, by which they are re-arranged and become conductors. A slight shake or tap disturbs them, and the current re-arranges them; and by this process signals are easily sent. For long distances, or when objects intervene, masts are set up to carry the wave-exciting wires, and by these means communication has been easily made across the Straits of Dover, and more recently the distance has been extended to 200 miles, between the Isle of Wight and Cornwall; while for short distances of a few miles no masts are required, but only the two electrical circuits and the receivers, which can be easily carried from one place to another.

One of the most recent developments by Mr Marconi is to so adjust the transmitting and receiving instruments to each other that only the person in possession of the adjusted receiver can read the message. It is asserted that, by the new instruments, an admiral can either send a message which can be read by the captains of every ship in the fleet, or can send special messages to any one ship, which no other will be able to receive.

It is not anticipated that this wireless telegraphy will, to any large extent, take the place of the present system, but that it will be of the greatest service in special conditions under which ordinary telegraphy is not available is certain; while its extension to great distances, even across the Atlantic, is said to have been already accomplished.

We thus see that, during the nineteenth century, two distinct modes of communication with persons at a distance have been discovered and brought into practical use, both

of which are perfectly new departures from the methods which, with but slight modifications, had been in use since that early period when picture-writing or hieroglyphics were first invented.

In the facilities and possibilities of communication with our fellow-men all over the world, the advance made in the present century is not only immensely greater than that effected during the whole preceding period of human history, but it has led to the most marvellous results, far beyond even the imagination of the most advanced men of science in preceding centuries. And it is also much greater in amount than the almost simultaneous advance in facilities for locomotion, great as these have been.

CHAPTER V

FIRE AND LIGHT

"Put out the light, and then—put out the light!
If I quench thee, thou flaming minister,
I can again thy former light restore,
Should I repent me:—but once put out thy light,
Thou cunning'st pattern of excelling nature,
I know not where is that Promethean heat
That can thy light relume."
Othello.

It seems probable that the discovery of the use of fire, and of some mode of producing it at will, constituted the first important advance of primitive man towards obtaining that command over nature which we term civilisation. How long ago it is since that first step was taken we have no means of determining. The palæolithic cave-dwellers made use of fire, and no tribes of men have been found who were wholly unacquainted with it. It was probably first utilised in volcanic districts, where sticks may often be ignited by thrusting them into cavities in old lava streams. In other regions, trees are often ignited when struck by lightning; and when this was first observed, the agreeable warmth, the ease with which the fire could be kept up by adding fresh fuel, the cheerful blaze at night, and the pleasant taste imparted to many kinds of food by roasting, would almost certainly lead to its careful preservation, and its distribution to other families and tribes. When once used, the inconvenience of losing it would be so great, that any clue to its mode of production would be followed up It is said that trees are sometimes ignited by

the friction of dry branches which happen to touch each other when violently rubbed together during a strong wind. When this was observed for the first time by some thoughtful savage, and he actually found that strong rubbing did make things hot, he would be encouraged to use his utmost efforts to imitate the effect produced by nature. After many unsuccessful trials, he would at length succeed, and the important news would be rapidly communicated to adjacent tribes, and thus spread over a whole continent. As a matter of fact, this method of producing fire by friction is that most common among savages in all parts of the world; and, since it requires only materials that are almost everywhere at hand, it descended even to some civilised peoples. (Fig. 42.) It is, however, a rather troublesome process, requiring a considerable amount of skill and perseverance; hence, some of the lowest savages, such as the Tasmanians, are said to have been without the knowledge of it, keeping their fires constantly alight, or, when accidentally extinguished, obtaining it from some adjacent tribe. Perhaps, however, the dampness of their forests rendered it practicable only during very dry seasons.

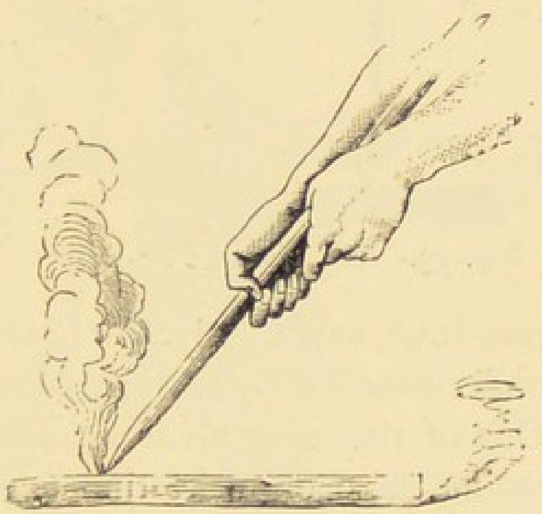


Fig. 42.—Fire obtained by Friction

A somewhat improved method is by causing a piece of hard wood to revolve rapidly between the hands, the pointed end being firmly pressed on a piece of very dry, soft wood, as shown in Fig 43. This was still further improved by using a small bow, the string of which is

twisted round the stick, and causes it to revolve much more rapidly than by the hands alone. This is called the fire-drill, and was used by some of the tribes of North American Indians, and other more advanced savages.

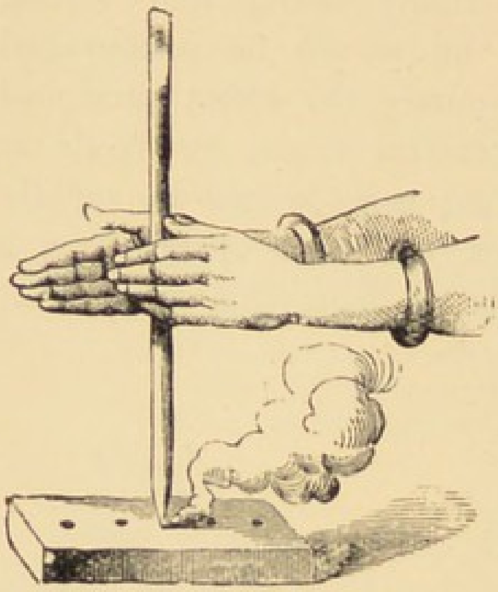


Fig. 43.—The Simple Fire-Drill

The more convenient method of striking a light by the use of flint, steel, and tinder probably originated after iron was first made, and soon became adopted by all civilised people, and by many savages who possessed iron; and this method continued in use from the times of pre-historic man through all the ages of barbarism and civilisation down to the early part of the last century, and the process underwent hardly any improvement during that long period. One of the most vivid recollections of my childhood is of seeing the cook make tinder in the evening, by burning old linen rags, and in the morning, with flint and steel, obtain the spark which, by careful blowing, spread sufficiently to ignite the thin brimstone match, from which a candle was lit, and fire secured for the day. (Fig 44.) The process was, however, sometimes a tedious one; and if the tinder had accidentally got damp, or if the flint were worn out, after repeated failures a light had to be obtained from a neighbour. At that time, there were few savages in any part of the world but could obtain fire as easily as the most civilised of mankind.

At length, after the use of these rude methods for many thousand years, a great discovery was made which revolutionised the process of fire-getting. The properties of

phosphorus were known to the alchemists, and it is strange that its ready ignition by friction was not made use of to obtain fire at a much earlier period. It was, however, both an expensive and a dangerous material, and though, about a hundred years ago, it began to be made cheaply from bones, it was not used in the earliest friction-matches. These were invented in 1827, or a little earlier, by

Fig. 44.—Tinder Box, Flint, Steel, and Brimstone Matches

Mr John Walker, a chemist and druggist of Stockton-on-Tees, and consisted of wood splints dipped in chlorate of potash and sulphur mixed with gum, which ignited when rubbed on sandpaper. Two years later the late Sir Isaac Holden invented a similar match. About 1834, phosphorus began to be used with the other materials to cause more easy ignition, and by 1840 these matches became so cheap

as to come into general use in place of the old flint and steel. They have spread to every part of the world, and their production constitutes one of the large manufacturing industries of England, Sweden, and many other countries.

Here again we have an invention that is not a modification of the old methods of obtaining fire, but a new departure, possessing such great advantages that it rapidly led to the almost total abandonment of the old methods in every civilised country, as well as in many of the remotest and least civilised parts of the world. For many thousands of years the means of obtaining fire remained almost unchanged over the whole world, till, only seventy years ago, a discovery which at the time seemed of but little importance, has led to a new method, which is so widely adopted that millions of persons in all civilised countries make use of it every day of their lives.

Artificial Light

Coming now to the use of fire as a light-giver, we find that an even greater change has taken place in our time. The first illuminants were probably torches made of resinous woods, which will give a flame for a considerable time. Then the resin exuding from many kinds of trees would be collected and applied to sticks or twigs, or to some fibrous materials tied up in bundles, such as are still used by many savage peoples, and were used in the old baronial halls. For out-door lights, torches were used almost down to our times, an indication of which is seen in the iron torch-extinguishers at the doors of many of the older west-end houses; while, before the introduction of gas, link-boys were as common in the

streets as match-sellers are now. Then came lamps, formed of small clay cups, holding some melted animal fat, and a fibrous wick, and, somewhat later, rushlights and candles. Still later, vegetable oils were used for lamps, and wax for candles; but the three modes of obtaining illumination for domestic purposes remained entirely unchanged in principle, and very little improved, throughout the whole period of history down to the end of the eighteenth century. The Greek and Roman lamps, though in beautiful receptacles of bronze or silver, were exactly the same in principle as those of the lowest savage, and hardly better in light-giving power; and though various improvements in form were introduced, the first really important advance was made by the Argand burner. This introduced a current of air into the centre of the flame as well as outside it, and, by means of a glass chimney, a regular supply of air was kept up, and a steady light produced. (Fig. 47.) Although the invention was made at the end of the eighteenth century, the lamps were not sufficiently improved and cheapened to come into use till about 1830; and from that time onward, many other improvements were made, chiefly dependent on the use of the cheap mineral oils, rendering lamps so inexpensive, and

Fig. 45.—A "Link-Boy" with Torch

producing so good a light, that they are now found in the poorest cottages.

The only important improvement in candles is due to the use of paraffin fats instead of tallow, and of flat, plaited wicks, which are consumed by the flame. In my boyhood, the now extinct "snuffers" were in universal use, from the common, rough iron article in the kitchen to elaborate, polished steel spring snuffers, of various makes, for the parlour, with pretty metal or *papier-maché* trays for them to stand in. Candles are still very largely used, being more portable and safer than most of the paraffin oil lamps. Even our lighthouses used only candles down to the early part of the nineteenth century.

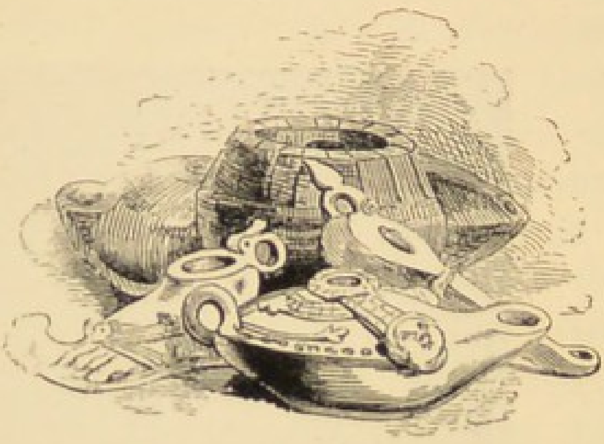


Fig. 46.—Greek and Roman Lamps

Owing to their long-continued use, and their intimate connection with our social life, both candles and lamps have afforded to our poets many striking comparisons with the shortness of human life, and the contrasts of night and day. Thus Shakespeare says:

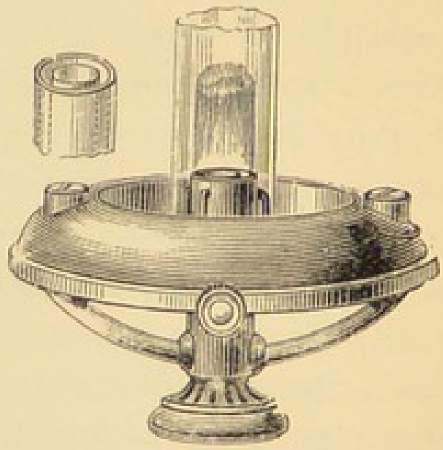


Fig. 47.—An Argand Oil-Lamp

> "My oil-dried lamp and time-bewasted light
> Shall be extinct with age and endless night."

And again:

> "These eyes like lamps whose wasting oil is spent
> Wax dim."

While he refers to candles in no less than twenty-three passages, of which the following are well-known examples:

> "How far that little candle throws his beams!
> So shines a good deed in a naughty world."

And these exquisite lines:

> "Night's candles are burnt out, and jocund day
> Stands tiptoe on the misty mountain-tops."

Should these ancient and humble modes of illumination altogether cease to be used, the above allusions, and hundreds of others everywhere pervading our literature, will lose much of their interest and beauty, and may even, in time, require the help of the antiquarian commentator to render them intelligible.

Gas and Electric-Lighting

A far more important and more radical change in our modes of illumination was the introduction of gas-lighting. A few houses and factories were lighted with gas at the very end of the eighteenth century, but its first application to out-door or general purposes was in 1813, when Westminster Bridge was illuminated by it, and so successfully that its use rapidly spread to every town in the kingdom, for lighting private houses as well as shops, streets, and public buildings. When it was first proposed to light London with gas, Sir Humphry Davy is said to have declared it to be impracticable, both on account of the enormous size of the needful gasholders, and the great

danger of explosions. These difficulties, have, however, been overcome, as was the supposed insuperable difficulty of carrying sufficient coal in the case of steamships crossing the Atlantic; the impossibilities to one generation becoming the common experience of the next.

Still more recent, and more completely new in principle,

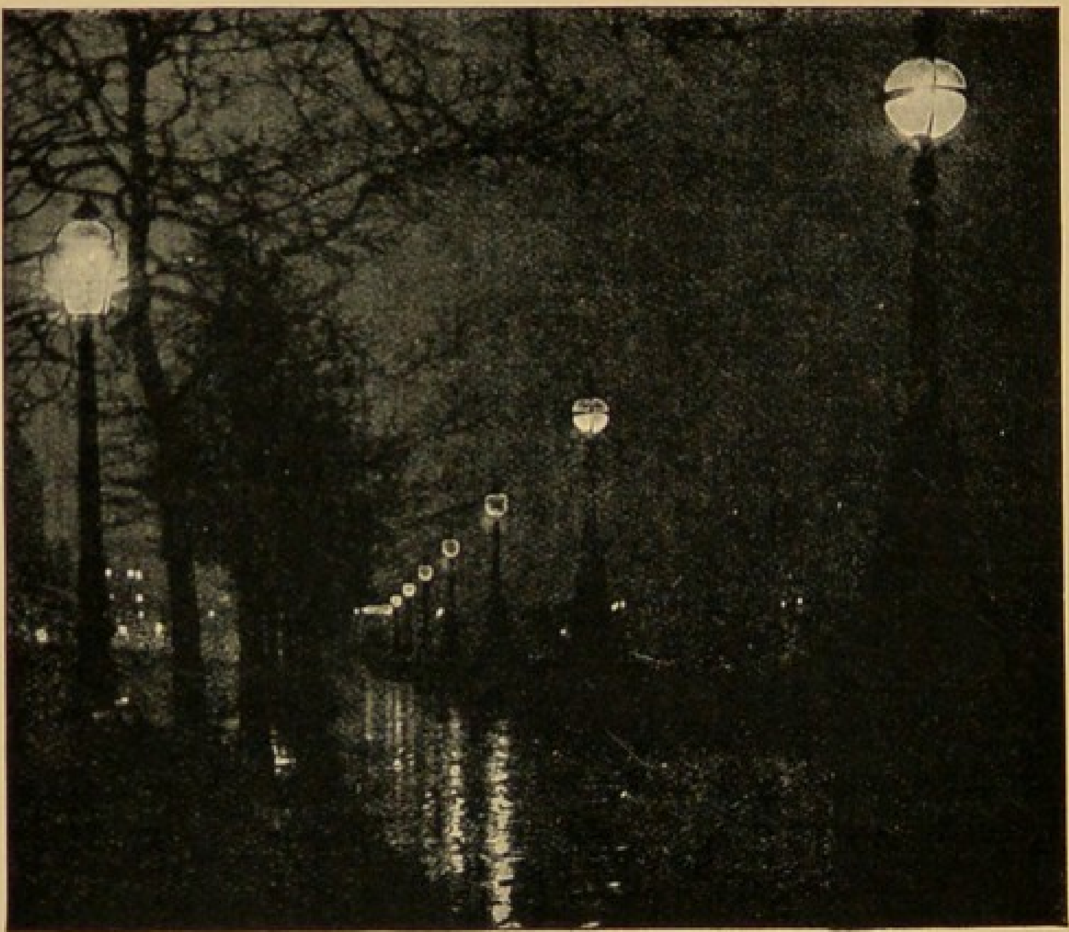


Fig. 48.—The Thames Embankment lit up by Electric Lamps

is the electric light, which has already attained a considerable extension for public and private illumination (Fig 48), and is almost as superior to gas as that was to oil-lamps and candles. It is also applicable to many purposes for which all other kinds of light are quite unsuitable, and is

thus capable of extending our knowledge in various directions.

Small incandescent lamps are now used for examinations of the larynx and in dentistry, and a lamp has even been introduced into the stomach by which the condition of that organ can be examined. For this last purpose numerous ingenious arrangements have to be made to prevent possible injury, and by means of prisms at the bends of the tube the operator can inspect the interior of the organ under a brilliant light. Other internal organs have been explored in a similar manner, and many new applications in this direction will no doubt be made. In illuminating submarine boats, and in exploring the interior of sunken vessels, it does what could hardly be effected by any other means, while it is now proposed to use it in the illumination of the profound depths of the ocean so as to obtain photographs of the various forms of life that exist there.

We thus find that whereas, down to the end of the eighteenth century our modes of producing and utilising light were almost exactly the same as had been in use for the preceding two or three thousand years, in the nineteenth century we made no less than four new departures, all of which are far superior to the methods of our forefathers. These are—(1) the improvement in lamps by the use of the principle of the Argand burner and chimney; (2) lighting by coal-gas; (3) the discovery and universal use of friction matches; and (4) the various modes of electric lighting. The amount of advance in this one department of domestic and public illumination during the past century is enormous, while the electric light has opened up new fields of scientific exploration.

Whether we consider the novelty of the principles

involved, or the ingenuity displayed in their application, we cannot estimate this advance at less than that effected during the whole preceding period of human history, from that very remote epoch when fire was first taken into the service of mankind, down to the time of men now living among us.

CHAPTER VI

NEW APPLICATIONS OF LIGHT—PHOTOGRAPHY

"O portrait, bright and wonderful!
  Wrought by the sun-god's pencil true;
What grace of feature, glance of eye!
  The soul itself beams out from you.

New marvel of a marvellous age!
  Apelles old, whose art 'twas said
Rivalled reality, than this
  Had never limned a lovelier head." *

THE improvements in the mode of production of light for common use, discussed in the previous chapter, are sufficiently new and remarkable to distinguish this century from all the ages that preceded it, but they sink into insignificance when compared with the discoveries which have been made as to the nature of light itself, its effects on various kinds of matter leading to the art of photography, and the complex nature of the solar spectrum leading to spectrum analysis. This group of investigations alone are sufficient to distinguish the present century as an epoch of the most marvellous scientific discovery.

Although Huygens put forward the wave-theory of light more than two hundred years ago, it was not accepted, or seriously studied, till the beginning of the

* The above translation of the Pope's Latin verse on Photography is by my friend, Mr F. T. Mott, of Leicester.

"Expressa solis spiculo
  Nitens imago, quambene
Frontis decus, vim luminum
  Refers, et oris gratiam.

O mira virtus ingeni,
  Novumque monstrum! Imaginem
Naturæ Apelles æmulus
  Non pulchriorem pingeret."

nineteenth century, when it was revived by Thomas Young, and was shown by himself, by Fresnel, and other mathematicians, to explain all the phenomena of refraction, polarisation, and interference, some of which were inexplicable on the Newtonian theory of the emission of material particles, which had previously been almost universally accepted. The complete establishment of the undulatory theory of light is a fact of the highest importance and will be dealt with at some length in our next chapter.

From a more practical point of view, however, nothing can surpass in interest and importance the discovery and continuous improvement of the photographic art, which has now reached such a development that there is hardly any science or any branch of intellectual study that is not indebted to it. A brief sketch of its origin and progress will therefore not be uninteresting.

Early History of Photography

The fact that certain salts of silver were darkened by exposure to sunlight was known to the alchemists in the sixteenth century, and this observation forms the rudiment from which the whole art has been developed. The application of this fact to the production of pictures belongs, however, wholly to our own time. In the year 1802 Wedgwood described a mode of copying paintings on glass by exposure to light, but neither he nor Sir Humphry Davy could find any means of rendering the copies permanent. The first permanent light-pictures were produced by Niepce of Châlon. He did not, however, use salts of silver, but bitumen dissolved in oil of turpentine or lavender, a material which is rendered in-

soluble by light, whereas the parts not exposed remain soluble. Bitumen pictures were thus formed on glass or polished metal with inequalities of surface due to variations of solubility, and this kind of natural etching could be printed. It did not lead to any great development, but the method is said to be still used in Prussia for the production of banknotes. Bitumen is also used in the beautiful printing process termed photogravure, which will be referred to latter on.

The Daguerrotype

The first process which became so generally useful as to be a commercial success was that of the daguerrotype in 1839. Daguerre's process consisted in exposing silvered plates to the vapour of iodine, producing a film of iodide of silver. This undergoes chemical changes when exposed to light, but unless the exposures are very long no visible result is produced. But if, after a short exposure, when no change is visible to the eye, the plates are subjected to the action of mercury-vapour, a distinct and beautiful picture at once appears. By immersion in a solution of salt or of hypo-sulphite of soda the image is fixed and the perfect daguerrotype is produced.

This was the first completely successful mode of obtaining pictures by the agency of light, and it was especially adapted to portraiture. Although expensive, and now altogether superseded by other processes, which admit of more rapid production and multiplication, it is not inferior to any of them in delicacy and beauty. It came into general use about the year 1840, and a portrait of myself, taken in 1848, is still quite perfect, except a little discoloration on the outer edges of the plate.

Modern Photography

What may be termed modern photography was started on its successful career by Mr Fox Talbot, who began experimenting with salts of silver on paper in 1833, and soon discovered means of producing great sensitiveness, and, what was much more important, a method of fixing the pictures by soaking them in a solution of common salt, or of iodide or bromide of potassium. He also discovered suitable developers, which brought out pictures before invisible. Several of his processes were patented, and he received a Royal Society medal in 1842 in recognition of the value of his discoveries.

At this early date he already produced photographic landscapes, portraits, and very perfect copies of engravings and drawings; but as both negatives and positives were taken on paper, the grain of which, as well as the unequal expansion and contraction, when wetted and dried were unfavourable to minute detail, they did not have a very wide application till later investigators overcame these difficulties.

The next great step was the use of albumen upon glass on which to take the negative, which was then printed on sensitive paper. This enabled much more delicate pictures to be obtained than with paper-negatives. Albumen was soon superseded by collodion—a preparation from gun-cotton, which was first used for photographic purposes by Mr Scott Archer in 1850. This substance was easily applied to glass, forming a delicate film upon it, and, when prepared with salts of silver, gave a beautiful negative picture, which has never been surpassed.

The first use of the collodion film on glass was to take negatives in a camera-obscura, which, when placed on black

velvet, or when coated with a black composition, produced positive pictures almost as perfect and beautiful as the daguerrotype itself, and at much less cost. Positives were also printed from the transparent negatives on suitably prepared paper, and thus was initiated the process which, with endless modifications and improvements, is still in use. The main advance has been in the replacing of collodion by gelatine, and the continually increased sensitiveness of the photographic plates, so that, first moving crowds, then breaking waves, running horses, and other quickly moving objects were taken, while now a bullet fired from a rifle can be photographed in the air.

Another great step has been the dispensing with the glass plate by the use of flexible gelatine or celluloid dry plates, which are always ready for use, and can be carried almost any distance without injury. This, combined with ever-increasing sensitiveness, has led to the construction of light and portable cameras, by means of which the traveller can secure invaluable records of every passing scene or aspect of nature, and has brought about the almost universal use of photography by travellers in every part of the world.

An almost equal advance has been effected in photographic printing. The old processes for printing positives from negatives were very slow, requiring sunshine or bright daylight. Now, extremely sensitive paper allows artificial light to be used with almost instantaneous exposure, and machines have been constructed by which a band of sensitive paper of indefinite length passing under or over a negative is checked for an instant while exposed to light, and then passes on through a developing bath, and is afterwards fixed and dried, allowing of many thousands of copies per hour being produced; and also, where required for book-illustrations, being printed by

two negatives on both sides of the paper. But such elaborate arrangements are now superseded by the great improvement in what are termed process-plates.

The Carbon Process

Before describing the various methods of reproducing photographs by the use of the ordinary printing-press, or by lithographic or engraving processes, we must notice the distinct and beautiful modification of photography termed the carbon process. This depends on the peculiar action of bi-chromate of potash on gelatine, which was discovered by the early experimenters so far back as 1838. Gelatine, rendered sensitive by bi-chromate of potash, becomes insoluble in warm water by being exposed to light, while when not exposed it remains soluble.

For what is termed the "carbon process," paper is used coated with gelatine which has been coloured with any permanent pigment. For ordinary purposes it is coloured with lamp-black, and to the eye is jet-black in colour. This black gelatine film is rendered sensitive by the bi-chromate solution, and is exposed under an ordinary photographic negative. This exposure to light renders the gelatine insoluble to a depth proportioned to the amount of light which has acted upon it. The soluble portions of the film are, of course, on the side next the paper. The gelatine film is therefore soaked off and transferred to another sheet of paper, which now has the soluble side uppermost. By the use of warm water all the soluble portion is washed away, leaving the film of unequal thickness in exact proportion to the amount of exposure to light, and thus reproducing all the delicate lights and shadows of the original from which

the negative was taken. The picture is now complete, and is as permanent as an engraving; but where thought necessary, the gelatine film may be again transferred to specially prepared paper or other surface for the purpose of book-illustration or for framing.

As in all such processes, the manipulations are elaborate, and considerable skill is required to ensure success; but the results are very beautiful, exhibiting the detail of a good photograph with an entire absence of gloss, which renders it more like an exquisite black-and-white drawing.

Ink-Printing from Photographs

As all ordinary photographs in which salts of silver are used are subject to fading or discoloration, and are, besides, too slow and expensive for ordinary book and magazine illustration, innumerable efforts have been made to discover methods of reproducing and printing photographs in permanent ink as rapidly and perfectly as when wood-blocks are used. A few years ago the thing seemed almost impossible, yet we have now arrived at what may well be termed perfection, since in every illustrated magazine we find landscapes and portraits reproduced from photographs, which for all purposes of illustration are as good as the photograph itself, but which are, nevertheless, printed in the same press and with the same ink as the letterpress accompanying them. As this great and complete success has only been attained within the last twenty years of the century, we will first describe some of the earlier processes which are still in use for special purposes, and each of which possesses certain distinctive beauties and advantages.

Woodbury-Type

This beautiful process was invented and brought to perfection so long ago as 1866, and still ranks as perhaps the most perfect method of reproducing photographs by printing with permanent ink, but as it is somewhat costly it is only used for illustrating the more expensive works.

The first step is to get a relief-picture in gelatine by the bi-chromate process, in the same way as for a carbon-print, but a thicker film of plain gelatine is used. The gelatine picture is hardened by the use of spirit, and is then laid down on a thick plate of steel. Upon the uneven surface of the gelatine a plate of lead is laid, and by means of a powerful press this is slowly forced to take an impression of the gelatine surface, but in this copy the lights are elevated while the shadows are depressed. From the same gelatine-film large numbers of metal reliefs can be obtained without injury.

This metal plate being accurately bedded in a special press, some almost liquid ink, prepared with gelatine, is poured on its centre. A specially-prepared paper, coated with shellac and highly pressed between polished steel plates, is laid on the ink, covered with a thick plate of glass, and subjected to great pressure. The ink is thus so completely forced away from the more elevated portions of the plate that the paper becomes almost pure white in the high lights, and every gradation of tone is produced between white and black. The ink firmly attaches itself to the paper, and, when quite dry, is fixed by a solution of alum, and can then be mounted in the usual way. The pictures thus obtained are so wonderfully like actual photographs that they bear magnifying as well as the originals, while as they can be printed in ink of any colour, and with

pigments that are quite permanent, they are in this respect equal to any other printing process.

Collotype

This process also depends on the peculiar action of the bi-chromate salts upon gelatine when exposed to light. But in this case the soluble portions are not washed away, but are left in order to hold moisture, while the insoluble parts quickly dry. We thus have a surface varying in the amount of retained moisture, just as in a lithographic stone. When greasy printing-ink is applied to such a surface it is rejected by the wet portions while it adheres to those that are nearly or quite dry, and when carefully printed a good picture results. The success of this process depends upon the fact that the gelatine film, before being used, is artificially dried, and this produces a minute grain on the surface, which greatly helps the production of the half-tones. In this process there are many details in the manipulation of extreme delicacy, and the printing also requires special care. When everything is skilfully managed the results are very beautiful, having a softness and delicacy of tint, together with a minuteness of detail which can hardly be surpassed.

Under the term "photo-lithography," a modification of this process is used to transfer photographs of engravings, drawings, or other works of art to lithographic stones, from which they are printed by the usual methods of lithography.

Photogravure

This is a rather new and beautiful French process now coming into use. The first steps are the obtaining

of a photographic picture on the carbon-gelatine film, as described for the carbon process; but a positive instead of a negative is used to print from, the result being an undeveloped carbon negative on paper—that is, with a paper backing.

The next process is to cover a polished copper plate with very finely powdered bitumen. By a special apparatus this is spread over the plate with perfect regularity. The plate being slightly heated, the bituminous dust melts sufficiently to adhere to the plate, producing a minutely granulated surface. The carbon negative is then wetted and transferred to the plate, to which it adheres, and the paper backing, as well as the soluble parts of the gelatine, are washed away.

When this is dry we have a negative carbon picture, with all the delicate gradations of thickness which produced the beautiful carbon prints. This is placed in a bath of perchloride of iron, which passes through the thinner parts of the gelatine, and eats away the copper in exact proportion to the thickness of the gelatine film.

When washed and thoroughly dried this etched plate is treated as if it were one of the old hand-engraved copper plates. It is inked with a dabber and all the surplus ink wiped off, leaving a surface on which the quantity of ink is exactly proportioned to the varying tints in the original photograph, and, when carefully printed, by great pressure, produces a soft, delicately-shaded picture, very much in the style of the collotype, but perhaps even more refined.

The Half-Tone Process

The above term is applied specially to the mode of reproducing photographs used in almost all illustrated

papers, magazines, and books at the end of the nineteenth century. It differs from the various processes already described by the facility and perfection with which the process-plates can be printed along with the letterpress. If any of these illustrations are closely examined they are found to consist of a regular series of minute dots, so close together that at the ordinary distance at which we read a book they are invisible, fusing together into the varying gradations of light and shade that make up the picture. By using a low-power lens, however, we see that the dots are smaller in the lights and larger in the shadows, in the highest lights being very small and faint in tint, while in the deepest shadows they run into each other so as to be quite black. If we consider each of these little dots to correspond to a letter of type, the white spaces between them being sunk, while the dots of varying sizes are raised to nearly the same level, we shall be able to understand how it is that such a plate can be printed by inking with a roller, as in ordinary book-printing. The method used to bring about this result is briefly as follows:—

In order to produce this series of dots or "grain" in the plate, a piece of gauze was first used, and the result was fairly good for coarse work. Now, however, special glass screens are always employed. These are thin plates of glass on which parallel lines have been engraved at distances varying from 85 to 175 to an inch, according to the delicacy required in the picture. The lines on the glass are filled with a black pigment, the thickness of the lines being somewhat less than the width of the spaces between them. Two of these ruled glasses are placed face to face, so that the lines cross each other at right angles, and the edges are cemented together, thus forming a permanent screen.

In taking the negative the camera is made so as to allow this screen to be placed immediately in front of the sensitive plate, but not quite touching it. The image on the sensitive plate is therefore made up of spots of light of uniform size, but of different intensities. Where the light is brightest, the chemical action on the sensitive film being more rapid, the spot is slightly enlarged, while in the shadows the action is much slower and the spots are both smaller and fainter. As so much of the light is stopped by the screens, a somewhat longer exposure is needed than when they are not used.

From this negative a zinc or copper plate is prepared for printing from. A polished copper plate is sensitised with a bi-chromate salt in some kind of albumen or gelatine, much as in the photogravure process. The negative is laid upon it and exposed to light, and the plate is afterwards developed by washing, which clears away the gelatine from the spaces between the dots, leaving them of the varying sizes due to the action of the varying amounts of light, as already described.

The plate must now be etched by an acid, or other chemical solvent, which eats away all the spaces between the dots to a sufficient depth for printing. When this is properly done there remains a series of very minute dots in the parts which are to print lightest very slightly below the level of the dark parts, where the copper surface is almost continuous or only slightly shadowed by minute hollows at the intersection of the crossed lines.

In every part of this process the most careful attention to details is required, and there are numerous modifications in every stage which would not be intelligible to anyone not practically familiar with the work. Here, as in all the other processes by which mechanical prints are obtained from photographs, the beauty and perfec-

tion of the results are far beyond anything that could be anticipated from the apparently inadequate means which are employed.

An Early Prediction of Photography

Before describing some of the important applications of photography to the arts and sciences, the following curious passage from an old French writer, Tiphaiyni de la Roche, is of special interest. It occurs in a book entitled "Giphantie," which is full of fantastic ideas, and the prediction of photography almost parallels that of Swift as to the discovery by the Laputans of the two satellites of Mars. We are indebted to Mr W. J. Harrison's "History of Photography" for the quotation as here given. The author supposes himself to be travelling in an unknown country, where his guide shows him all the sights and curiosities, and speaks to him thus: "You know that rays of light reflected from different bodies form pictures, paint the image reflected on all polished surfaces; for example, on the retina of the eye, on water, and on glass. The spirits have sought to fix these fleeting images; they have made a subtle matter by means of which a picture is formed in the twinkling of an eye. They coat a piece of canvas with this matter, and place it in front of the object to be taken. The first effect of this cloth is similar to that of a mirror, but by means of its viscous nature the prepared canvas retains a facsimile of the image. The mirror represents images faithfully, but retains none; our canvas reflects them no less faithfully, but retains them all. This impression of the image is instantaneous. The canvas is then removed to a dark place. An hour

later the impression is dry, and you have a picture the more precious that no art can imitate its truthfulness."

Applications of Photography

With such marvellous powers, photography has come to the aid of the arts and sciences in ways which would have been perfectly inconceivable to our most learned men of a century ago. It furnishes the meteorologist, the physicist, and the biologist with self-registering instruments of extreme delicacy, and enables them to preserve accurate records of the most fleeting natural phenomena. By means of successive photographs at short intervals of time we are able to study the motions of the wings of birds, and thus learn something of the mechanism of flight; while even the instantaneous lightning-flash can be depicted, and we thus learn, for the first time, the exact nature of its path.

The Cinematograph

Among the most striking results of rapid photography is the production of what are termed living pictures by the above-named instrument. Its action depends upon the fact that the impression of any object on the retina is not instantaneous only but persists for a definite time, which is about one-third of a second. This explains why a burning stick moved rapidly backwards and forwards or in a circle looks like a continuous band of fire. Also if a toothed wheel rotates quickly the teeth cannot be seen in ordinary light, but if it is suddenly illuminated by an electric spark it appears as if quite still and the separate teeth becomes visible. This is because the duration of the light is not so great as the time occupied by a tooth moving

over the space between two adjacent teeth. If, then, a series of instantaneous photographs of a moving object are taken at intervals not greater than the duration of impressions on the retina, and the successive pictures are exhibited at similar intervals, during which time each figure has moved a little onward and is in a slightly different attitude, they will not be seen as separate pictures, but will appear as if continuously in motion, because the images in one picture persist till the next one, which is so like it that the difference is not perceived, takes its place. When such a series of pictures, magnified to life-size, are thrown on a screen, the effect is very striking, and with proper adjustments of light the appearance is deceptively like a real scene passing before the spectators. The accompanying illustration (Fig. 49) shows one of these sets of instantaneous pictures which, when exhibited in rapid succession, produce the effect of life and motion.

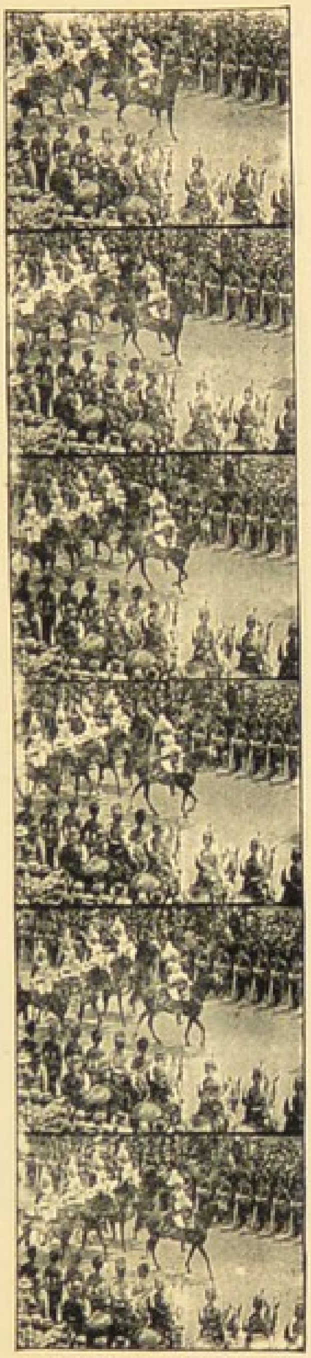


Fig. 49.—Portion of a Moving Object Photo. The Jubilee Procession. (Mark the gradual change in position of men and horses.)

Photographing the Stars

Perhaps, however, the most marvellous of all the achievements of photography is in the field of astronomy. Every increase in the size and power of the telescope has revealed to us ever more and more stars in

every part of the heavens; but, by the aid of photography, stars are shown which no telescope that has been, or that probably ever will be constructed can render visible to the human eye. For, by exposing the photographic plate in the focus of the object glass for some hours, almost infinitely

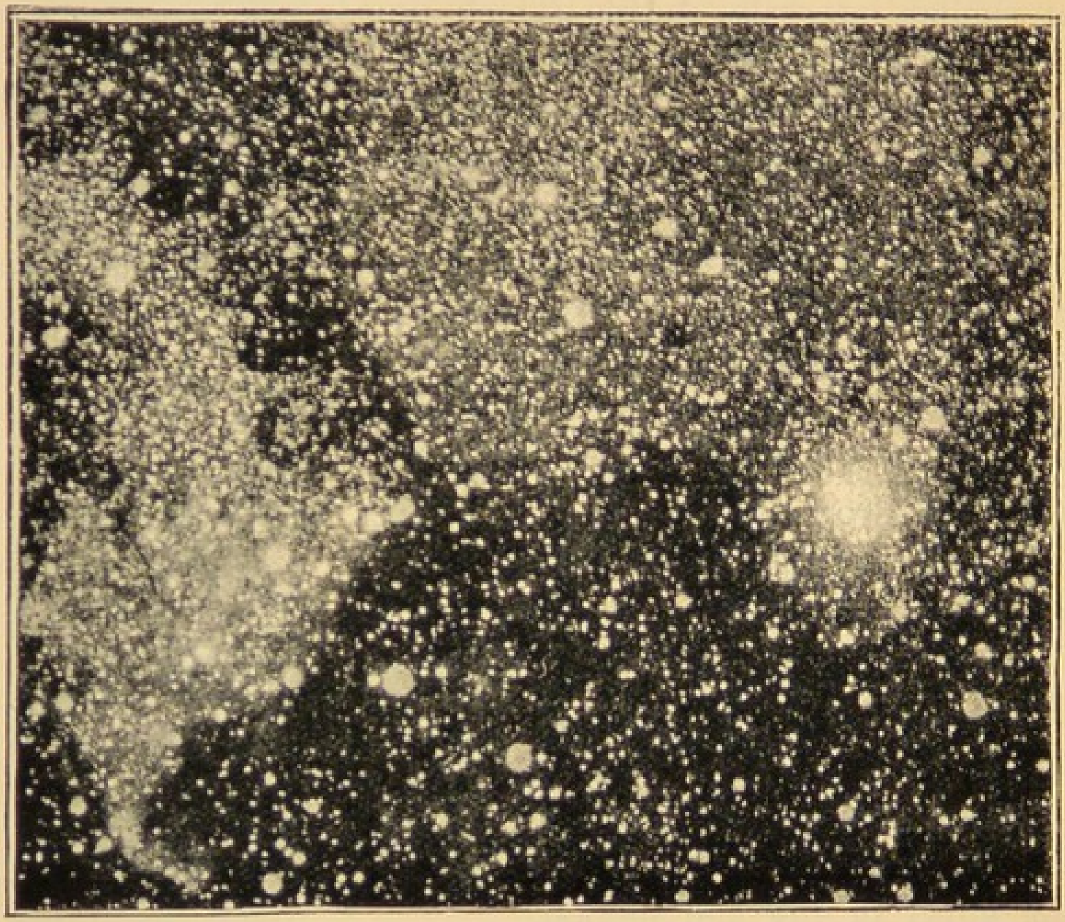


Fig. 50.—A Star Photograph

faint stars impress their image, and the modern photographic star-maps show us a surface densely packed with white points that seem almost as countless as the sands of the sea-shore (Fig. 50). Yet every one of these points represents a star in its true relative position to the visible stars nearest to it, and thus gives at one operation an amount of accurate detail which could hardly be equalled by the

labour of an astronomer for months or years—even if he could render all these stars visible, which, as we have seen, he cannot do. A photographic survey of the heavens is now in progress on one uniform system, which, when completed, will form a standard for future astronomers, and thus give to our successors some definite knowledge of the structure, and, perhaps, of the extent of the stellar universe. Other applications will be referred to later on in chapters devoted to the New Astronomy.

The X-Rays

The most recent of all the discoveries in connection with light and photography, and one which extends our powers of vision in a direction, and to an extent, the limits of which cannot yet be guessed at, is that peculiar form of radiation termed the X or Röntgen Rays, from Professor Röntgen of Würzburg, who was the first to investigate their properties and make practical applications of them. These rays are produced by electrical currents sent through vacuum-tubes, which excite luminosity in various fluorescent substances, or in the glass of the tubes. Along with the luminous rays are other radiations which, though invisible, have the property of passing through many substances quite opaque to ordinary light, and also of being stopped by many ordinary transparent substances. Paper, for instance, is so transparent that the rays will pass through a book of a thousand pages, or through two packs of cards, both of which would be absolutely opaque to the most brilliant ordinary light. Aluminium, tin, and glass of the same thickness are all transparent, but they keep out a portion of the rays; whereas platinum and lead are quite opaque. To these rays aluminium is two hundred times

as transparent as platinum. Wood, carbon, leather, and slate are much more transparent to the X-Rays than is glass, some kinds of glass being almost opaque, though quite transparent to ordinary light. Flesh and skin are transparent in moderate thicknesses, while bone is opaque (Fig. 51).

Hence, if the rays are passed through the hand, the bones cast a shadow, though an invisible one; and as, most fortunately, the rays act upon photographic plates almost

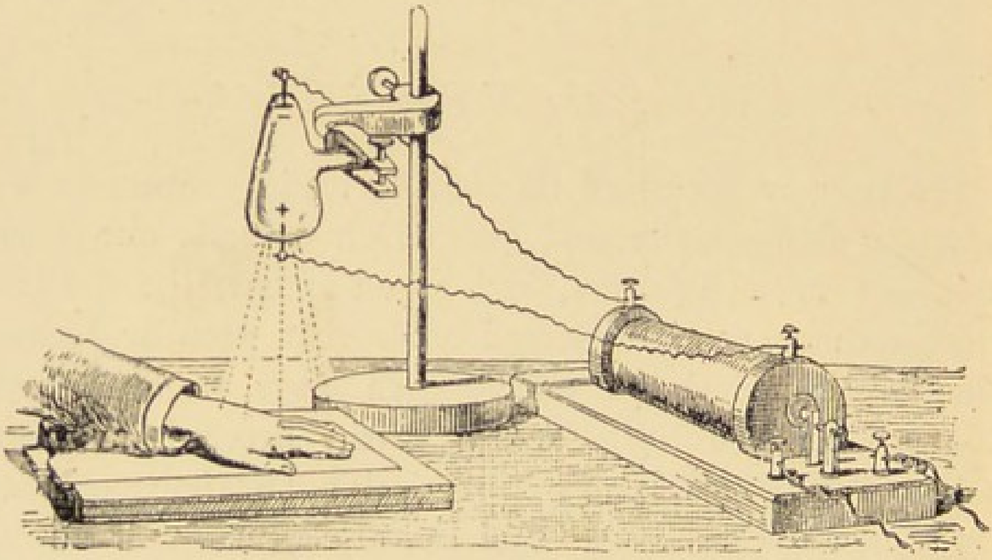


Fig. 51.—An X-Rays Apparatus

like ordinary light, hands or other parts of the body can be photographed by their shadows, and will show the bones by a much darker tint. Hence their use in surgery to detect the exact position of bullets or other objects embedded in the flesh or bone. (See Fig. 52.) A needle which penetrated the knee joint, and then broke off, leaving a portion embedded which set up inflammation, and might have necessitated the loss of the limb, was shown so accurately that a surgeon cut down to it, and got it out without difficulty.

An exceptional property of these rays is that they cannot

be either refracted or reflected as can ordinary light and heat. Hence it is only the shadow that can be photographed. And another curious result of this is that they can pass through a powder as easily as through a solid; whereas ordinary light cannot pass through powdered glass or ice owing to the innumerable reflections and refractions which soon absorb all the rays except those reflected from a very thin surface layer. Proportionate thicknesses of aluminium or zinc in the solid plate or in powder are equally transparent to these singular rays.

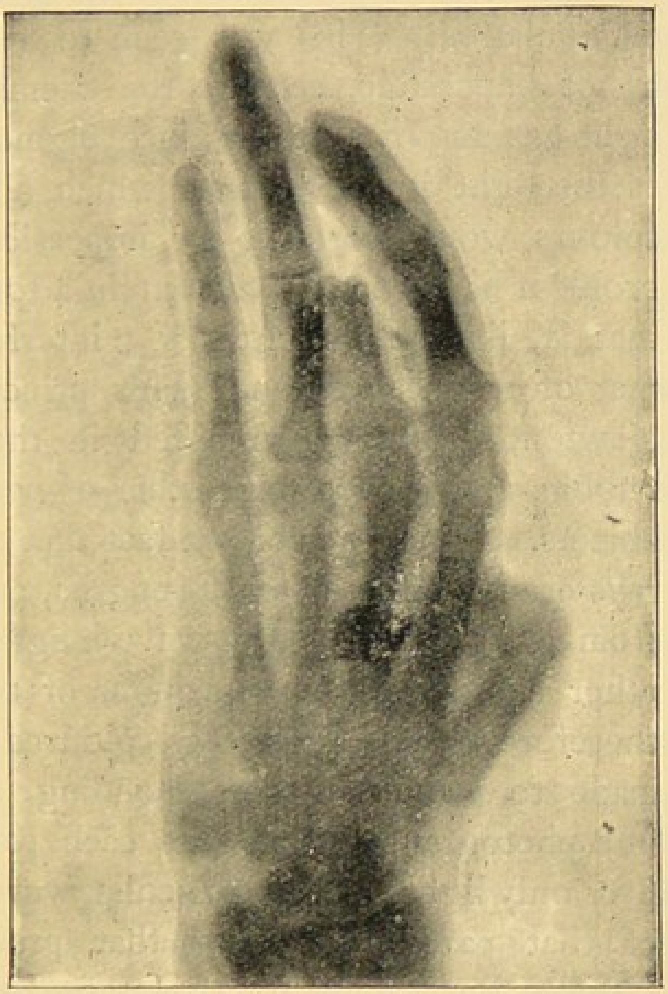


Fig. 52.—A Röntgen-Ray Photo, showing Bones of Hand and a Finger-Ring
(*From a Photo by F. G. Stuart, Southampton*)

So much is already popular knowledge on this subject that it is unnecessary to go into further details here, where it has been introduced on account of its connection with photography. The nature and origin of these rays in connection with other forms of radiation will be considered in a later chapter.

Colour Photography

It has long been the dream of photographers to discover some mode of obtaining pictures which shall reproduce all the colours of nature without the intervention of the artist's manipulation. This was seen to be exceedingly difficult, if not impossible, because the chemical action of coloured light has no power to produce pigments of the same colour as the light itself, without which a photograph in natural colours would seem to be impossible. Nevertheless, the problem has been solved, but in a totally different manner; that is, by the principle of "interference" instead of by that of chemical action. This principle was discovered by Newton, and is exemplified in the colours of the soap bubble, and in those of mother-of-pearl and other iridescent objects. It depends on the fact that the differently-coloured rays are of different wave-lengths, and the waves reflected from two surfaces half a wave-length apart neutralise each other and leave the remainder of the light coloured. If, therefore, each differently-coloured ray of light can be made to produce a corresponding minute wave-structure in a photographic film, then each part of the film will reflect only light of that particular wave-length, and therefore of that particular colour that produced it. This has actually been done by Professor Lippmann of Paris, who published his method in 1891; and in a lecture before the Royal Society, in April 1896, he fully described it, and exhibited many beautiful specimens.*

The method is as follows:—A sensitive film, of some of the usual salts of silver in albumen or gelatine, is used, but with much less silver than usual, so as to leave the film quite transparent. It must also be perfectly homogeneous, since any granular structure would interfere with

* This lecture is reported in "Nature," vol. liii. p. 617.

the result. This film on glass must be placed in a frame so constructed that at the back of it there is a shallow cell that can be filled with mercury which is in contact with the film. It is then exposed in the usual way, but much longer than for an ordinary photograph, so that the light-waves have time to produce the required effect. The light of each particular tint being reflected by the mercury meets the incoming light and produces a set of *standing* waves—that is, of waves surging up and down, each in a fixed plane. The result is, that the metallic particles in the film become assorted and stratified by this continued wave-action, the distance apart of the strata being determined by the wave-length of the particular coloured light—for the violet rays about eight-millionths of an inch; so that in a film of ordinary thickness there would be about five hundred of these strata of thinly-scattered metallic particles. The quantity of silver used being very small, when the film is developed and fixed in the usual way, the result is not a light-and-shade negative, but a nearly transparent film which, nevertheless, reflects a sufficient amount of light to produce a naturally coloured picture.

The principle is the same for the light-waves as that of the telephone for sound-waves. The voice sets up vibrations in the transmitting diaphragm, which, by means of an electric current, are so exactly reproduced in the receiving diaphragm as to give out the same succession of sounds. An even more striking and, perhaps, closer analogy is that of the phonograph, where the vibrations of the diaphragm are permanently registered on a wax cylinder, which, at any future time, can be made to set up the same vibrations of the air, and thus reproduce the same succession of sounds, whether words or musical notes. So the rays of every colour and tint that fall upon the

plate throw the deposited silver within the film into minute strata which permanently reflect light of the very same wave-length, and therefore of the very same colour as that which produced them. These strata have been proved to exist by making a photo-micrograph of a section of the film.

The effects are said to be most beautiful, the only fault being that the colours are more brilliant than in nature, just as they are when viewed in the camera itself. This, however, may perhaps be remedied (if it requires remedying) by the use of a slightly opaque varnish. The pictures also require to be viewed in a particular light, and the colours produced are not always, to the eye, true representations of those in nature. The comparatively little attention that has been given to this beautiful and scientifically-perfect process is no doubt due to the fact that it is rather expensive, and that the pictures cannot, at present, be multiplied by any printing process. But for that very reason it ought to be especially attractive to amateurs, who would have the pleasure of obtaining exquisite pictures which will not become commonplace by indefinite reproduction.

There are some other processes in common use for producing coloured pictures from photographs, but none of them are, in any true sense, photography in colours. They all require screens and filters of three colours, through which photographs are taken, each giving the light-and-shade effects which are produced by one colour alone. These three different light-and-shade photographs are then each viewed through a coloured glass of nearly the same tint as that of the filter, so as to reproduce, as closely as possible, the natural colours which were effective in that picture, and these three single-coloured pictures are by an ingenious system of reflectors combined into one. Some-

times the results are very beautiful and natural, in other cases glaring and unnatural, and, as the pictures can only be viewed in a rather elaborate instrument, they have none of the advantages which have made photographs so popular.

In another process the negatives are taken through a screen ruled with very fine coloured lines of three colours alternately over the whole screen, and a positive from this negative is viewed through a similar screen adapted to reproduce the natural tints when each line is exactly superposed over the corresponding line of the taking screen. This is said to be well adapted for lantern-slides, and to produce very good effects.

In yet another process the three negatives taken through coloured screens are printed on gelatine films on celluloid plates. These films are prepared with potassium bichromate, and the action of light renders the gelatine insoluble, so that in the shadows in the original (but which are light in the negative) the gelatine remains, while the lights are represented by the bare celluloid. Each of these three films is then dyed with a complementary colour to that which produced the corresponding negative, and the three coloured transparencies thus obtained are mounted over each other between glass, producing lantern-slides which are said to give very good results.

The most recent method is by the use of three different diffraction gratings in a very ingenious manner, which give colourless pictures unless viewed from one point, when they appear naturally coloured.

It will now be seen that the problem of photography in natural colours is as far from being attained as ever. In not one of these processes is there any particle of colour produced by the action of light upon the chemicals

employed in the same sense as the varied lights and shadows are produced in ordinary photography, and till this is done there can be no true "colour photography." To view light-and-shade photographs through coloured glasses, or coloured line-screens, or dyed transparencies, can no more be called photography in colours than can the beautiful coloured photographs now manufactured in Switzerland.

Lippmann's process is the only one in which the light itself reproduces the colours of nature; but as this result is attained not by pigments but by the production of a wave-structure in the film, the colours have a metallic brilliancy (as in all interference colours) which does not accurately reproduce the soft and infinitely varied tones of nature's pictures, besides having the other disadvantages already referred to.

The chemicals that are acted upon by light are very few in number, and not *one* of those yet discovered is so acted upon by light of any colour as to reproduce that colour instead of a mere neutral shade. But in order to have a true colour photography the chemicals used must reproduce *every* colour in all their infinite varieties of tone and tint. As no approach to such a result has yet been hit upon, and as there is no reason to think that any such substances exist, those who have most studied the subject believe that true photography in colours will never be attained.

Colour-Screens for Ordinary Photography

One of the chief defects of the ordinary photographic processes is the very erroneous representation of natural light and shade it affords, due to the fact that the actinic

power of the blue end of the spectrum is very much greater than that of the red and yellow ends. Hence a fair but ruddy face comes out swarthy in a photograph; and the luminous effect in a picture of two ladies, one in a bright yellow dress, the other in a deep blue, are reversed, the former seeming to be dark the latter nearly white. The same difficulty occurs in landscapes, where the green foliage comes out too dark and spotty; and colours which are strongly contrasted in nature, as red and green, sometimes produce hardly any difference of tint in the photograph.

These defects are not of very great importance in out-door views because the perfection of light and shade and infinite delicacy of detail render such pictures not only beautiful, but accurate and artistic reproductions of what, under some lights and at some time of the year, does (or may) occur in nature. But in the reproduction of paintings of the great masters it is essential to have a tolerably accurate reproduction of the lights and shadows as given by the artist. For this purpose a screen of tinted yellow glass is placed before the lens or before the sensitive plate. The effect of this is to absorb a portion of all the rays except the yellow; therefore the exposure must be longer, and this gives more time for the yellow light to act on the plate, while the diminished amount of the other rays, especially of the blue, causes them to act less powerfully. The general result is to equalise the action of the red and the blue ends of the spectrum and thus produce a more accurate light-and-shade representation of the actual colours, whether in a picture or in nature. This method is now always used in the best photographic copies of great paintings, the tint of the yellow glass being deeper when dark yellows and browns predominate in the picture. It is also necessary

to use ortho-chromatic plates which are especially sensitive to yellow light.

Colour-printed Photographs

There are two distinct methods of producing these mechanically-coloured photographs. That which has been brought to some perfection in America is a process method. Three or four negatives are taken through coloured screens. From each of these a process-plate is made; and each of these plates is printed in colour on the same paper, producing a coloured picture. The results shown by specimens in the Process Year-Book for 1900 are, however, very unequal, portraits being generally far better than landscapes. A great deal, of course, depends on the choice of the pigments used in printing, which must be such that, when superposed, they blend in natural intermediate tints. In many of the pictures thus produced this is not the case, and the general effect is often muddy and unnatural, while in others the contrasts are harsh and glaring. Simple objects such as birds' eggs are, however, beautifully reproduced by some such process.

The Swiss Coloured Photographs

Far more beautiful and true to nature than any of the colour-process-plates yet in use are the Swiss pictures already referred to. The tints in these have the softness and transparency of nature, and there are none of those dark and muddy or harsh and glaring colours which are so commonly found in the process-prints. The exact method of producing these is a secret, but I am informed by an expert in photographic work of all kinds that it is

probably as follows:—A good photograph is taken in which the shadows are not very dark. At the same time, a good artist sketches the same view in water-colours. From the coloured sketch a number of stones are prepared, each to print one colour on exactly the same scale as the negative. These several tints are then printed on a suitable paper to take the colours, which are clear and transparent. The positive photograph printed on a very then film of gelatine is then transferred to the coloured paper so as accurately to register with the colours, which are thus preserved in all their purity, while the lights and shadows are given by the photograph only. In this way there is produced a more accurate as well as a more beautiful photographic picture in colours than by any other process yet discovered; while, though not so cheap as process-plates, they are yet very little more costly than common black-and-white photographs.

The New Art of the Nineteenth Century

The brief sketch of the rise and progress of photography now given illustrates the same fact which we have already dwelt upon in the case of other discoveries. This beautiful and wonderful art, which already plays an important part in the daily life and enjoyment of all civilised people, and which has extended the bounds of human knowledge into the remotest depths of the starry universe, is not an improvement of, or development from, anything that went before it, but is a totally new departure. From that early period, when the men of the Stone Age rudely outlined the mammoth and the reindeer on stone or ivory, the only means of representing men and animals, natural scenery, or the great events of human history,

Fig. 53.—Commodore Byron making Presents to the Patagonians

had been through the art of the painter or the sculptor. It is true that the highest Greek, or Mediæval, or Modern art cannot be equalled by the productions of the photographic camera; but great artists are few and far between, and the ordinary, or even the talented draughtsman can give us only suggestions of what he sees, so modified by his peculiar mannerism as often to result in a mere caricature of the truth. Should some historian in Japan study the characteristics of English ladies at two not remote epochs, as represented, say, by Frith and by Du Maurier, he would be driven to the conclusion that there had been a complete change of type, due to the introduction of some foreign race, in the interval between the works of these two artists. From such errors as this we shall be saved by photography; and our descendants in the middle of the coming century will be able to see how much, and what kind, of change really does occur from age to age.

The importance of this is well seen by comparing any of the early works on ethnology, illustrated by portraits intended to represent the different "types of mankind," with recent volumes which give us copies of actual photographs of the same types; when we shall see how untrue to nature are the former, due probably to the artist having delineated those extreme forms, either of ugliness or of beauty, that most attracted his attention, and to his having exaggerated even these.

In an "Abridgement of Byron's Voyage round the World in 1764-66" (in "The Modern Traveller," 1776), it is stated that a Patagonian they met was "near 7 ft. high," and that "few of these Indians were shorter than the height mentioned above, and the women as high." It is also stated that "Mr Cumming, the first lieutenant, though 6 ft. 2 ins. high, was himself astonished at the

Fig. 54.—A Sailor giving a Patagonian Woman a Biscuit for her Child

diminutive figure he cut among the Indians, who were broad and muscular in proportion to their height." The two engravings here copied (Figs. 53 and 54) are given in the above-named work, and were, perhaps, designed to illustrate the above-quoted passages. The second seems to apply to the statement of Pigafetta, who accompanied

Fig. 55.—Specimen Line Block
(*Drawing by F. G. Stuart, Southampton*)

Magellan, and who relates that their tallest sailor only came up to the waist of the first man they met. It is now known that the average height of Patagonian men is about 5 ft. 10 ins., or 5 ft. 11 ins., and none have been found to exceed 6 ft. 4 ins. Photography would have saved us from such an error as this.

The great range and value of the commonest and cheapest form of photographic reproduction—the process-plate—

is well shown by the accompanying three specimens of ordinary book-illustration. Fig. 55 shows a reproduction of an artist's ink drawing, which is hardly distinguishable from an etching or wood-cut.

Fig. 56.—Specimen Half-Tone Block—Fine Grain

(*From a Painting by Greuze*)

Fig. 56 is a print from a photograph of an oil-picture, which has the delicacy of an Indian-ink drawing or a fine mezzotint engraving, the dots of which it is composed

being only visible on very close examination, or by the use of a magnifying glass.

Our third illustration (Fig. 57) is an example of how figures in active motion can be pictured for us with a life-like accuracy and perfection which is beyond the

Fig. 57.—An Instantaneous Photograph
(*From Photo by R. W. Thomas, Cheapside, London*)

reach of any but the greatest masters of design. And the facility for producing such pictures is now so great that we have presented to us in our books and periodicals scenes of public and private life in every part of the world, enabling us to realise the manners and customs and the material surroundings of foreign peoples in a way that no earlier epoch has ever enjoyed.

There will, however, always be work for good artists, especially in the domain of colour and of historical design; but the humblest photographer is now able to preserve for us and for future generations minutely accurate records of scenes in distant lands, of the ruins of ancient temples which are sometimes the only record of vanished races, and of animals or plants that are rapidly disappearing through the agency of man. And, what is still more important, they can preserve for us the forms and faces of the many lower races which are slowly but surely dying out before the rude incursions of our imperfect civilisation.

That such a new and important art as photography should have had its birth, and have come to maturity so closely coincident with the other great discoveries of the century already alluded to, is surely a very marvellous fact, and one which will seem more extraordinary to the future historian than it does to ourselves, who have witnessed the whole process of its growth and development.

CHAPTER VII

LIGHT: ITS NATURE AND PROPERTIES

"Hushed be all earthly rhymes!
List to those spheral chimes
That echo down the singing vaults of night.
The quivering impulse runs
From the exultant suns,
Circling in endless harmonies of light."
F. T. MOTT.

THERE is no department of human knowledge in which the nineteenth century has witnessed more important and marvellous progress than in those which deal with light and the various radiant phenomena connected with it, such as heat and, perhaps, electricity.

The undulatory theory of light was clearly put forth by Huygens in the seventeenth century, and he showed how it explained the phenomena of refraction and double refraction. But it was not accepted by his scientific contemporaries, and was almost ignored till Thomas Young, in 1801, observed what is called the interference of light, and showed that this phenomenon could be explained if light consisted of minute waves in some medium filling space, termed the "ether," but could not be explained by the corpuscular theory of Newton. Other students, especially Fresnel and Malus, devoted themselves to the subject, and showed that all the curious phenomena of the polarisation of light by reflection from glass and refraction through various crystals, could also be explained on the wave-theory, which thenceforward became universally accepted. On

this theory colour arises from the fact that the undulations or waves in the ether vary greatly in length and rapidity of vibration, but all alike travel through it at the same rate. This is analogous to the fact that all sounds travel through the air at the same rate, though the length of the air-waves and velocity of their vibrations vary greatly. If a band is heard at a considerable distance, at night or over water, the different notes from the lowest to the highest, and from such different instruments as a drum and a cornet, reach the ear in their proper order just as if they were only a few yards off. It is owing to the different wave-lengths of the differently-coloured rays of light that, when they are refracted, by passing obliquely through glass or other transparent substance, they diverge from each other and form what is termed a spectrum.

The solar spectrum is that coloured band produced by allowing a sunbeam to pass through a prism, and a portion of it is seen in the dewdrop or the crystal when the sun shines upon them; while the complete band is produced by the numerous raindrops, the coloured rays from which form the rainbow. Newton examined the colours of the spectrum very carefully, and explained them on the theory that light of different colours has different refrangibilities—or, as we now say, different wave-lengths. He also showed that a similar set of colours can be produced by the interference of rays when reflected from the two surfaces of very thin plates, as in the case of what are termed Newton's rings, and in the iridescent colours of thin films of oil on water, of soap bubbles, and many other substances.

The eighteenth century added hardly anything to our knowledge of the spectrum, although Dollond discovered how to construct achromatic object-glasses by combining lenses of flint and crown glass, which require different curvatures in order to produce spectra of equal lengths.

But at the very beginning of the nineteenth century the properties of the spectrum began to be investigated. It had already been noticed that the heating power varied in different parts of it, the violet end giving the least heat, the red end most. But Sir William Herschel, in 1800, found, to his surprise, that just outside the red end of the spectrum there was still considerable heat; and immediately afterwards Professor Ritter of Jena found that the chemical effects of light, as shown by its power of blackening nitrate of silver, was partly due to the action of the violet rays, but much more powerfully to the invisible rays beyond the extreme end of the spectrum. It was thus shown that the visible spectrum is only a portion, and, as has since been shown, only a small portion, of the whole body of radiation emitted by the sun: and these facts also rendered it highly probable that heat and light were identical in nature, heat being the more fundamental, since the whole of the ether-waves, so far as yet known, produce heat-effects, as determined, not by our sensations only, but by delicate thermometers; whereas our eyes are, as it were, attuned to perceive a certain limited portion of the rays through which alone we experience the sensations of light and colour. Hence, when referring to ether-waves generally, the term "radiations" is more appropriate than "light."

But a far more important step was taken about the same time. In the year 1802 the celebrated chemist, Dr Wollaston, made the remarkable discovery that the solar spectrum, when closely examined, is crossed by very numerous black lines of various thicknesses and at irregular distances from each other. Later, in 1817, these lines were carefully measured and mapped by Fraunhofer. (*See* Fig. 58, the upper curved line showing variations of heat.) But their meaning remained an unsolved problem till about

the year 1860, when the German physicist, Kirchhoff, discovered the secret, and opened up to chemists and astronomers a new engine of research whose powers are probably not yet exhausted.

It was already known that the various chemical elements, when heated to incandescence, produce spectra, consisting of a group of coloured bands, and it had been noticed that some of these bands, as the yellow band of sodium, corresponded in position with certain black lines in the

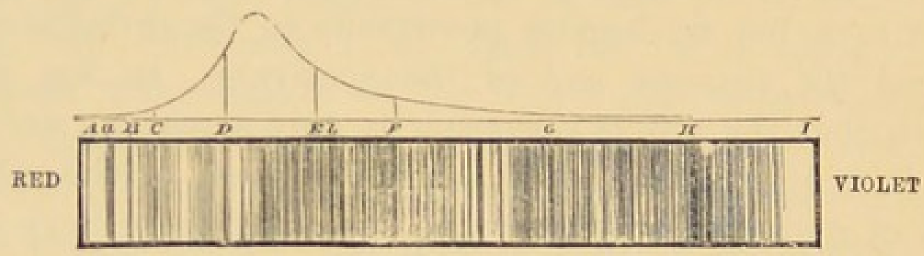


Fig. 58.—Solar Spectrum

solar spectrum. Kirchhoff's discovery consisted in showing that, when the light from an incandescent body passes through the same substance in a state of vapour, much of it is absorbed, and the coloured bands become replaced by black lines. The black lines in the solar spectrum are due, on this theory, to the light from the incandescent body of the sun being partially absorbed in passing through the vapours which surround it. This theory led to a careful examination of the spectra of all the known elements, and on comparing them with the solar spectrum it was found that in many cases the coloured bands of the elements corresponded exactly in position with certain groups of black lines in the solar spectrum. Thus hydrogen, sodium, iron, magnesium, copper, zinc, calcium, and many other elements have been proved to exist in the sun. Some outstanding solar lines, which did not correspond to any known terrestrial element, were supposed

to indicate an element peculiar to the sun, which was therefore named helium. Quite recently this element has been discovered in a rare mineral, "cleveite," and its coloured spectrum is found to correspond exactly to the dark lines in the solar spectrum on which it was founded, thus adding a final proof of the correctness of the theory, and affording a striking example of its value as an instrument of research.

The immediate effect of the application of the spectroscope to the stars was very striking. The supposition that they were suns became a certainty, since they gave spectra similar in character and often very closely resembling in detail that of our sun; but this subject will be discussed later in our chapters on astronomy.

Equally important is the application of spectrum analysis to the discovery of new elements, and the indication it gives us of their affinities and the possibilities of splitting them up into more simple substances. One of its first applications in this field led to the discovery of the new metals *Cæsium* and *Rubidium* by Bunsen and Kirchhoff in 1860; and this was closely followed by Crookes' discovery of *Thallium* in 1861. Since that date many other new elements, including several new gases, have been detected by the same means.

Sir Henry Roscoe emphasises the extreme delicacy of the test it gives in the following passage:—

"A portion of sodium salt, less than the $\frac{1}{180,000,000}$th part of a grain, can be detected, and compounds are found to be most widely disseminated throughout the earth, which were supposed to occur very seldom. The extreme delicacy of the method is seen when we learn that every substance which has been exposed to the air, even for a moment, gives the soda line, every minute speck of dust containing sodium compounds in sufficient quantity to

produce the characteristic reaction when placed in a colourless flame. Thus, too, the lithium compounds, which were formerly supposed to be contained in only four minerals, by aid of spectrum analysis are found to be substances of most common occurrence, being observed in almost all spring waters, in tea, tobacco, milk, and blood, but existing in such minute quantities as to have altogether eluded recognition by the older and less delicate analytical methods. A portion of lithium, less than $\frac{1}{6,000,000}$th part of a grain, can thus be detected." *

The test, too, applies to every elementary substance, whether solid, liquid, or gaseous, and when these are heated to the degree at which their vapour becomes luminous, then each element emits the peculiar light given off by it alone, and the characteristic bright lines become visible when its spectrum is observed. Even the most refractory metals and other elements which cannot be sufficiently heated by an ordinary flame, when exposed to the electric spark passing between two points of the substance in question, are so intensely heated that small portions are volatilised and give off the peculiar light. Thus, even iron, platinum, and other metals may each be recognised by the characteristic bright lines seen in their spectra. Every gas, also, when electric sparks are passed through them, can be detected in the same manner, each showing its peculiar and often highly complex spectrum of bright lines.

Hence the spectroscope has given to the chemist a test which can be applied to all substances whatever. It is not only of extreme delicacy, but is of universal application; and among its other triumphs are the recent detection of five new gases in the atmosphere in very minute quantities, but each having its characteristic

* "Elementary Chemistry," p. 258.

spectrum. Further reference will be made to this powerful instrument of research in our chapters on chemical and astronomical discovery. The sketch of its nature and results here given is mainly for the purpose of illustrating our growing knowledge of the phenomena of light and colour, and as a preliminary to a brief outline of those even more remarkable phenomena which have culminated in what are termed X, or Röntgen rays.

The Kathode and Röntgen Rays

The concluding years of the century were characterised by the discovery of several forms of radiant energy so distinct from all before known — light, heat, and the chemical rays — as to constitute almost a new world of natural forces of great complexity. The starting-point of these phenomena was the observation of the effects of electrical discharges between two platinum wires sealed into glass tubes, from which almost all air has been exhausted by a mercurial air-pump.

When a current is sent through these wires, brilliant luminosity is produced within the tubes, varying in colour according to the particular gas or vapour a minute quantity of which remains in them. These are the well-known Geissler tubes. Later on, by means of improvements in the mercurial air-pump, Sir William Crookes produced much higher vacua, and constructed his well-known radiometer or "light-mill" described in the following chapter.

When the exhaustion of the air or gas is carried to a high degree, instead of sparks the electrical discharge produces a glow around the conductor, but separated from it by a dark space. With a still higher

exhaustion the dark space widens till it fills the tube; but the glass walls become beautifully phosphorescent, and streams of electrified molecules are projected from the surface of the kathode. Diamonds, rubies, and white powdered alumina become brilliantly phosphorescent when exposed to these discharges, and they have other remarkable properties—one of which is, that transparent as well as opaque substances cast shadows.

In Fig. 59 the kathode K is a disc of aluminium, and the cross in the path of the discharge is of mica, and its shadow is thrown on the end of the tube while all around it the glass is phosphorescent. If a part of the tube is formed of thin aluminium, the kathodic radiations pass through it and excite phosphorescence in substances outside it.

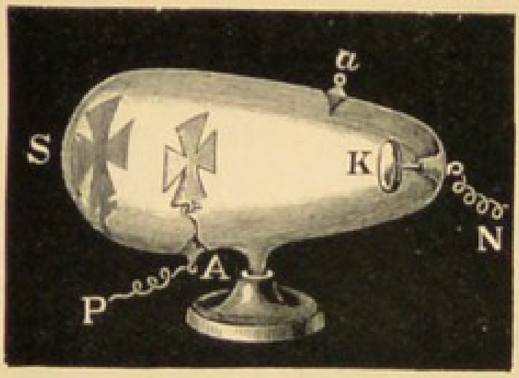


Fig. 59.—The Kathode Rays

From these comparatively well-known kathode rays, whose varied properties have been studied for many years, but are mainly of interest to specialists, arose one of the most sensational discoveries of the century, the Röntgen or X rays. Their properties were first discovered by Professor Röntgen of Würzburg in 1895, and their study has already produced a very extensive literature. Professor Röntgen found that if the kathode rays, in their vacuum tube, were enclosed in an opaque cylinder or muff made of blackened paper or cardboard, then, in a darkened room, if any fluorescent substance, such as barium platino-cyanide, is brought near to the apparatus, it lights up with a brilliant fluorescence which is visible up to a distance of six feet from the cylinder. This fluorescence

occurs even when the most opaque substances are interposed. Paper is so transparent to the rays that a thick book does not stop them. Pine boards, tin foil, and many other materials are equally transparent. When the hand was held before the fluorescent screen, the shadow showed the bones sharply defined but the flesh very faintly. These rays, though themselves invisible, act upon a photographic plate like ordinary light, and, owing to the fact that wood is transparent to them, the plate can be exposed to their action within its slide and in a light room. Shadow photographs can thus be obtained of the internal organs of animals and plants, as already explained in our preceding chapter. These rays have already become of great value in surgery, and as further improvements are made their uses will no doubt increase. (*See* Figs. 51, 52, pp. 114, 115.)

We are here, however, more interested in their general nature and properties than in the uses to which they can be applied. Like the kathode rays, from which they are derived, these rays cannot be either reflected or refracted, but on contact with any solid body not permeable by them they appear to be diffused laterally in all directions. They travel generally in straight lines, or they would not produce such well-defined shadows of the complex objects they permeate, and some physicists think them to be more in the nature of streams of minute particles of matter than any kind of vibrations of the ether.

From these Röntgen rays others with somewhat different properties have been produced. When they are allowed to fall on a metallic mirror, and are spread out or diffused by it, they are found to have less power of penetrating other bodies, and acquire properties which are to some extent dependent on the metal used. These have been called Secondary or S rays. If instead of a mirror a

perforated metallic plate is used, they are modified in a different way, and have been called Goldstein rays. All agree, however, in being invisible till they fall on some fluorescent substance, when luminosity is produced.

The Becquerel Rays

Another form of radiation, apparently allied to the Röntgen rays, was discovered by Professor Becquerel in 1896. He found that the salts of uranium emitted invisible radiations, which would pass through metals and other bodies opaque to light, as well as through glass and other transparent substances. They acted upon a photographic plate when covered with opaque paper, and they also discharged electrified bodies at a distance.

These rays are produced without any special exciting cause — such as electricity, heat, light, or a vacuum — and do not appear to be weakened even after the lapse of years. Like the Röntgen rays, these can neither be reflected, refracted, nor polarised.

It was next discovered (by M. and Madame Curie) that Bohemian pitchblende — a black, shiny ore of uranium — was even more actinic than uranium itself. This fact seemed to imply that the ore contained some other elements of very high actinic power, and an elaborate chemical research led to the discovery of two new substances, which have been named Polonium and Radium. Another chemist obtained a third substance, Actinium, from the same ore. The rays from these three substances are said to be 100,000 times as powerful as those of the ordinary uranium rays. They will excite fluorescent screens, discharge electrified conductors, and reproduce most of the properties of the Röntgen rays, but with special characteristic differences.

Sir William Crookes has also found a new substance in pitchblende, which possesses actinic properties, and which he has provisionally named *uranium x*. It seems to be most like radium. Whether these various substances are new elements is not yet decided; but it is said that radium possesses a characteristic spectrum.

The Becquerel rays will produce photographs showing the bones in the living body, but far less distinctly than the Röntgen rays, the cause of which seems to be their greater diffusion in passing through the flesh and through all light substances. Magnets are said to produce deviation in the rays from radium, and in some barium compounds, but not from polonium; but there is much divergence of opinion as to this phenomenon, which appears to vary according to the purity of the substances experimented with. Special chemical effects are produced by the luminosity excited by these rays.

The very varied and complex phenomena connected with these peculiar forms of radiation, of which only a few of the more prominent have been here noticed, lead to the conclusion that they are all really streams of very minute particles of matter, thrown off at enormous velocities, and more or less electrified. Many facts indicate that the particles in these streams are much smaller than the chemical atoms, and that they may perhaps be the primitive ions or even still smaller components of these; and they have been described as "an electric dance of atoms along the lines of force." Others suppose that they are streams of hydrogen atoms, which it is said to be impossible wholly to expel from the vacuum tubes. This view is supported by the fact that the spectrum of the glowing discharge of kathode rays always shows hydrogen lines.

On the other hand, the Röntgen rays, in many of their electrical and other properties, resemble the short-wave

rays of light at the violet end of the spectrum. The secondary rays from them, produced when they are diffused by contact with metallic surfaces, become more like ultra-violet light. They then lose their power of passing through opaque bodies. When the X rays are very strongly developed, they become faintly visible.

As bearing on this subject, we may note the experiments made more than thirty years since on the actinic effect of the invisible rays emitted from various substances. Thus, a printed page or a coin which for a long time had been in contact with, or even at a short distance from, a sheet of paper, were found to have left a faint impression upon it. These phenomena were explained by the supposition that very minute particles are given off by all bodies.

It was also found that various metals — zinc, nickel, magnesium, etc., and also printing ink, linseed oil, turpentine, most essential oils and varnishes — act upon a photographic plate by their emanations, as if they emitted light. What is more curious is that these substances will produce an impression through an intervening sheet of gelatine or paper, but not through glass, mica, or other transparent substances, thus indicating that the emanation it not any form of light. A piece of board laid upon a photographic plate will give a picture of its structure.

This series of strange, and often wholly unexpected, phenomena are of the highest interest, as affording fresh clues to that mysterious subject, the nature and constitution of matter. Taken in connection with the facts already referred to as to the diffusion of solids into each other, they seem to show that the molecules of matter are not only in motion, but are continually changing under the influence of the varied radiant forces—heat, light, and electricity—to which they are exposed. They act almost as if they were truly alive and subject to definite laws of

growth, decay, and death; and, in their process of decay, they appear to give rise to fresh life in the activity of those streams of minute radiating particles, the evidence of whose existence we have so recently obtained.

It is a suggestive fact that the two well-established elements which possess this radiant activity in the highest degree—uranium and thorium—are those which have the greatest atomic weights, and, presumably, the most complex atomic structure. Just as living organisms are built up of substances which are highly complex and unstable,—as in the various albumens and carbon-compounds, which so readily enter into new combinations under the influence of vital forces wherever required by the needs of the organism, —so the various forms of radiation we have been considering may be the means of keeping up a kind of inorganic circulation, analogous to that which occurs in living organisms, of which these obscure phenomena are the indications.

They serve to bridge over the chasm between the ethereal vibrations of heat, light, electricity, and magnetism, and the molecular movements of gases, liquids, and solids; and they may soon enable us to arrive at some definite conceptions as to the ultimate constitution of matter, and the real nature of molecules, atoms, and the ether.

The New Spectrum

There yet remains to be mentioned a very remarkable discovery by Mr S. P. Langley of Washington, which opens up a new mode of research, and may, perhaps, lead to a great extension of our knowledge of the forces that influence the material universe.

It has been long known that the visible spectrum did not include the whole of the radiant energy we receive from the sun. As already stated, Sir William Herschel, in the year 1800, found that heat-rays existed beyond the red end of the spectrum, and very soon afterwards the chemical effects of light were found to extend beyond the violet end. The length of the spectrum of these invisible chemical rays is very small, though they are very powerful; but beyond the red end chemical action also takes place, and, though less energetic, it extends to a much greater distance; so that, in 1886, Sir William Abney showed that a photographic spectrum extended beyond the red to a distance about equal to the whole length of the visible spectrum. In 1871, Lamansky proved that this invisible spectrum exhibited great variations of temperature, rising and falling irregularly, and it was this which led Mr Langley to the invention of the Bolometer—a kind of electrical thermometer, which, by successive improvements, has become so delicate that, while at first measuring one ten-thousandth of a degree centigrade, it now measures one hundred-millionth of a degree, and this with the greatest constancy and accuracy.

By the use of this wonderfully sensitive instrument, Mr Langley has extended the invisible spectrum to more than three times the extent (measured by the actual length of the light-waves) of the heat spectrum previously detected.

But this is only a portion, and perhaps the least important portion, of the work which he has done. The extreme delicacy of his instrument enabled him to detect variations in the heat of this invisible spectrum, which rises and falls so as to give five great, but unequal, maximæ, with corresponding minimæ between them. Then a more minute exploration showed that this irregularity was

due to the whole length of the spectrum being crossed by exceedingly fine bands of low temperature, exactly corresponding in general appearance and grouping to the black lines which cross the visible part of the solar spectrum. More than seven hundred of these "cold lines" have been detected and their position in the spectrum determined with great accuracy, Where they are few in number, the maximæ of temperature occur, where they are thickly grouped together, they produce the minimæ of temperature. Much of this work, which has extended over twenty years, was performed in the Sierra Nevada, at an altitude of 12,000 feet above the sea, where, in a calm and pure atmosphere, the slightest variations of heat in the spectrum could be detected.

The general result of the investigation is to show that the visible solar spectrum, with its glorious bands of colour and its large amount of heat and of chemical energy, yet contains only about one-fifth of the whole of the solar energy which reaches the earth, four-fifths of that energy being found in the invisible portion of the radiation. There is here opened up an altogether new field of research into the special properties of these radiations of great wave-length, and also to discover what are the elements or compounds whose absorbent powers produce the "cold lines" and the irregular distribution of heat throughout this part of the spectrum. The next half century will probably lead to some great discoveries on these points; but whether they are of a startling or useful nature or not, Mr Langley's pioneer work in this department must always give him a high rank among the physicists of the latter portion of the nineteenth century.

CHAPTER VIII

PHYSICAL PRINCIPLES AND THEIR APPLICATIONS

> "Yes, thou shalt mark with magic art profound,
> The speed of light, the circling march of sound."
>
> CAMPBELL.

> "O matchless Age! that even the passing tone
> Of epoch-making speech, or lover's sigh,
> Recordest for the wonder of all time!"
>
> F. T. MOTT.

THE theoretical discoveries in the domain of physics (besides those already referred to) have been very numerous, but only a few of them have enough generality or have become sufficiently popular to require notice in the present sketch. Two of these discoveries, however, stand above the general level as important contributions to our knowledge of the material universe. These are (1) the determination of the mechanical equivalent of heat leading to the general theory of the conservation of energy, and (2) the molecular theory of gases.

The Mechanical Equivalent of Heat

Down to the beginning of this century heat was generally considered to be a form of matter, termed caloric or phlogiston. The presence of phlogiston was supposed to render substances combustible, but when the chemical theory of combustion was discovered by Lavoisier, phlogiston, as the cause of combustion, disappeared, although

caloric, as the material basis of heat, still held its ground. Close to the end of the eighteenth century Count Rumford showed that in boring a brass cannon the heat developed in $2\frac{1}{2}$ hours was sufficient to raise $26\frac{1}{2}$ lbs. of water from the freezing to the boiling point. But during the operation the metal had lost no weight or undergone any other change; and as the production of heat by this process appeared to be unlimited, he concluded that heat could not be matter but merely a kind of motion set up in the particles of matter by the force exerted. Bacon and Locke had expressed similar ideas long before; and later Sir Humphry Davy showed that by rubbing together two pieces of ice at a temperature below the freezing point sufficient heat was produced to partially melt them; while other observers found that to shake water in a bottle raised its temperature, and that percussion or compression, as had been long known, produced a considerable amount of heat. These various facts led to the supposition that there was a mechanical equivalent of heat—that is, that a certain amount of force exerted or work done would produce a corresponding amount of heat; and Joule was the first to determine this accurately by a number of ingenious experiments. The result was found to be that a pound of water can be raised 1° C. by an amount of work equal to that required to raise one pound to the height of 1392 feet, or 1392 lbs. one foot. Various experiments with different materials were found always to lead to the same result, and thus the final blow was given to the material theory of heat, which was thenceforth held to be *a mode of motion of the molecules of bodies.*

These conclusions led to the more general law of the conservation of energy, which implies that in any limited system of bodies, whether a steam-engine or the solar

system, no change can occur in the total amount of the energy it contains unless fresh energy comes to it from without or is lost by transmission to bodies outside it. But as, in the case of the sun, some heat is certainly lost by radiation into space, unless an equal amount comes in from the stellar universe, the system must be cooling, and in sufficient time would lose all its heat, and therefore much of its energy. The chief use of the principle is to teach us what becomes of force expended without any apparent result, as when a ball falls to the ground and comes to rest. We now know that the energy of the falling ball is converted into heat, which, if it could be all preserved and utilised, would again raise the ball to the height from which it fell. It also enables us to trace most of the energy around us, whether of wind or water or of living animals, to the heat and light of the sun. Wind is caused by inequalities of the sun's heat on the earth; all water-power is due to evaporation by the sun's heat, which thus transfers the water from the ocean surface to the mountains, producing rivers; solar heat and light give power to plants to absorb carbonic acid and build up their tissues, and the energy thus locked up is again liberated during the muscular action of the animals which have fed directly or indirectly on the plants.

This great principle enables us to realise the absolute interdependence of all the forces of nature. It teaches us that there is no origination of force upon the earth, but that all energy either now comes to us from the sun or was originated in the sun before our earth came into existence; and we are thus led to the conclusion, that all work, all motion, every manifestation of power we see around us, are alike the effects of heat or of other radiant forces allied to it. This conclusion we

shall find is still further enforced by the next great discovery we have to notice.

The Molecular Theory of Gases

The very remarkable properties of gases, their apparently unlimited elasticity and indefinite powers of expansion, were very difficult to explain on any theory of their molecules being subject to such attractive and repulsive forces as seem to exist in other states of matter. A consideration of these forces, together with the power of diffusion, by which gases of very different densities form a perfect mixture when in contact, and the fact that by the application of heat almost all liquids and many solids can be changed into gases, led to the conception that they owed their peculiar properties to their molecules being in a state of intensely rapid motion in all directions. On this theory the molecules are very far apart in proportion to their size, and are continually coming in contact with each other. Owing to their perfect elasticity, they rebound without loss of motion or energy, and their continual impact against the sides of the vessel containing them is what gives to gases their great expansive force. From a study of these various properties it has been calculated that, at ordinary temperatures, there are some hundreds of trillions of molecules in a cubic inch of gas, and that these collide with each other eight thousand millions of times in a second. The average length of the path between two collisions of a molecule is less than the two-hundred-thousandth of an inch; yet this small length is supposed to be at least a hundred times as great as the diameter of each molecule.

From the fact that all gases expand with heat and

contract with cold, it is concluded that the ether-vibrations we term heat are the cause of the rapid motions of the gaseous molecules, and that if heat was entirely absent the motion would cease, and ordinary cohesive attraction coming into play, the molecules would come together and form solid masses. The practical demonstration of this theory constitutes one of the minor achievements of the nineteenth century, within which it was commenced and victoriously concluded only a few years short of its close by the complete liquefaction of hydrogen, the lightest and most essentially "gaseous" of all known bodies.

The Liquefaction of Gases

The properties of several vapours and gases had long ago suggested to physicists that at sufficiently low temperatures all gases could be liquefied and even solidified. We see the three states of water, solid, liquid, and vapour, within a very moderate range of temperature. Sulphurous acid is usually, with us, a gas, but near the poles it is a liquid; while ether, with us a liquid, is a gas in the tropics.

The more permanent gases were first liquefied by Faraday, when assistant to Sir Humphry Davy, in 1823. He used a very simple apparatus—a bent tube—in the lower end of which he placed some substance which would give off a gas with a slight heat. Then, sealing up the short end of the tube, the gas accumulates till it becomes highly compressed, and if the short end is kept cool the gas condenses into a liquid. In this way he liquefied carbonic acid gas by heating bi-carbonate of sodium; and also nitrous oxide, sulphuretted hydrogen, and several others, which do not require very intense cold or very

great pressures to liquefy them. He also observed a remarkable fact which has been the key to the later successes in this department of knowledge. When the tube containing one of these liquefied gases was opened it instantly began to evaporate, but the sudden expansion from liquid to gas cooled the remaining liquid still more, and the evaporation, therefore, went on very slowly, instead of almost instantaneously, as had been expected.

This cooling effect of evaporation, or of the escape of a gas from pressure, plays such an important part in the recent work in liquefying gases that a few words must be said about it. Every one knows the cooling effect on the skin even of tepid water if allowed to evaporate, and this cooling effect is greatly increased when liquids are used which evaporate more rapidly, such as alcohol or ether. On the same principle porous jars are used in very hot countries to cool water when placed in a current of warm air or even in the sunshine. The same thing happens with a gas as with vapour. Condensation heats, rarefaction cools. The former principle has been applied to obtaining a light by rapidly forcing a piston down a small cylinder, compressing the air so rapidly as to ignite a fragment of tinder at the bottom. And by the converse operation of continuously rarefying air, ice-making machines are constructed. These facts illustrate the law of the mechanical equivalent of heat and the molecular theory of gases. The energy expended in compression makes the gas hot; it soon loses this heat by contact with ice or cold water; then, when relieved from pressure, it

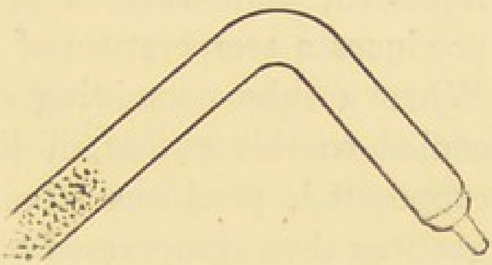


Fig. 60.—Faraday's Tube for Liquefying Gas

absorbs the heat required to keep its molecules apart and in more rapid motion, and thus lowers the temperature of its surroundings.

These principles could not, however, be put into practice till more perfect air-pumps and condensers had been constructed, and thus it was not till 1877 that the more permanent gases began to be liquefied. In that year, marsh-gas, acetylene, and oxygen were liquefied in Paris, Geneva, and Cracow. The method by which this result was obtained is as follows:—sulphurous acid gas is easily liquefied, and when it is allowed to evaporate freely it produces a temperature of 100° below zero of Fahrenheit. When a tube containing compressed carbonic acid gas is cooled to this extent, it liquefies, and when it is rapidly evaporated, produces intense cold of $-220°$ F. Oxygen gas was then compressed to 450 atmospheres and subjected to this intense cold. Then the pressure was removed, and the temperature was thereby so much lowered that a jet of liquid oxygen was produced, having a temperature of about $-250°$ F.

No further advance was made for some years, but from 1884 onwards, with improved methods and apparatus, it became possible to produce liquid air and many other gases in large quantities, and by their means to liquefy the most difficult of all gases—hydrogen. The method now used for producing liquid air in any desired quantity is exceedingly simple, and is thus described by Professor Ramsay. The air is first compressed by a pump to a pressure of 150 atmospheres. It then traverses a coil of copper pipe and escapes from an orifice at its *lower* end. By its sudden expansion heat is absorbed and the escaping air becomes cold, and in passing upwards over the coil of pipe by which it had descended (and which is enclosed in an outer vessel) it cools the pipe, so that the air passing down

becomes colder and colder; at last it becomes so much cooled that liquid air escapes from the orifice, and then its production continues indefinitely so long as the supply of compressed air is kept up. Liquid air is now a commercial product, and can be supplied at about a penny a gallon.

The liquefaction of hydrogen now became comparatively easy. The gas is compressed to 200 atmospheres, and is then cooled to $-300°$ F. by passing through a coil of copper pipe immersed in liquid air freely evaporating. The hydrogen thus cooled escapes at the bottom of the coil, and cools itself still more, till, after a short time, the hydrogen issues as a colourless liquid at a temperature of about $-400°$ F. By the use of liquid hydrogen the rare gas helium has also been liquefied at a still lower temperature.

Among other uses to which these low temperatures have been applied is that of obtaining a very near approach to true vacuum. If a glass tube containing pure air is placed in a bath of liquid hydrogen it almost instantly liquefies and then solidifies into ice, leaving the space above it an almost perfect vacuum. In such a tube having platinum wires sealed into it an electric current would not pass, or only with great difficulty and after slightly warming it. And as such high vacua can now be obtained in vessels of considerable size, many important experiments can be made. The latest achievement in the way of obtaining low temperatures was announced by Professor Dewar at the meeting of the British Association at Dover in 1899. This was the freezing of hydrogen into a snow-like mass and the attainment of a temperature of about 15° C. or 27° F. above the absolute zero. When we consider that this temperature is about twice as much colder than ice as ice is colder than boiling water we see how wonderful it is that such a result has been reached by such simple means,

Gradation of the States of Matter

The varied phenomena now briefly outlined lead us on to the next step in physics, that there is no such sharp line of distinction between the various states of matter as is popularly supposed, some of the properties which are characteristic of matter in one state being present in a less degree in other states. Viscous bodies, for example, often present phenomena characteristic of both solids and fluids. Sealing-wax, pitch, and ice are all brittle at moderately low temperatures, resembling in this respect such solids as glass and stone; but at the same temperature they are fluid, if time enough is allowed to exhibit the phenomena. This is seen in the motion of glaciers, which move in every respect like true fluids, even to the middle of the stream flowing quicker than the sides and the top than the bottom. Eddies and whirls occur in glaciers as in rivers, and also upward and downward motion, so that rocks torn off the glacier floor may be carried upwards and deposited on surfaces hundreds of feet above their place of origin. These properties can be shown to exist by experiment even on a small scale. A slab of ice, supported on its two ends, will become gradually curved, and the curvature may be increased to any desired extent if force is applied for a sufficient time. Models of glaciers in cobbler's wax, which is brittle at ordinary temperatures, exhibit all the phenomena of true glacier-motion, and serve to demonstrate the upward motions above referred to, which have been so often denied. Most metals exhibit similar phenomena under suitable conditions, and lead can be made actually to flow out of a hole under pressure.

One of the most characteristic properties of gases and of many liquids is that of mixing together when placed in

contact. But it has recently been shown that solids also mix, though very much more slowly. If a cube of lead is placed upon one of gold, the surfaces of contact being very smooth and true, and be left without any pressure but their own weight, and at ordinary temperatures, for about a month, a minute quantity of gold will be found to have permeated through the lead, and can be detected in any part of it. Metals may thus be said to flow into each other.

In order to produce chemical changes in bodies, it is usually necessary that one at least be a liquid or be in a state of solution, and the combinations that occur lead to the production of bodies having quite different properties from either of their components. Similar results happen when metals are mixed together, forming alloys. Thus a mixture in the proportion of 1 part lead, 1 part tin, and 2 parts bismuth produces an alloy which melts in boiling water while the component metals only melt at more than double that temperature.

A still more remarkable alloy is produced by a mixture of 8 parts lead, 15 parts bismuth, 4 parts tin, and 3 parts cadmium, since it begins to soften at 140° F. and becomes quite fluid at 149° F. Again, the strength of gold is doubled by the addition of one five-hundredth part of the rare metal zirconium, indicating that the alloy must have a new arrangement of the molecules. But the interesting point is that alloys can be produced without melting the metals, for mere pressure often produces an alloy at the surfaces of contact; while in other cases if fine filings of the component metals are thoroughly mixed together and then subjected to continued pressure, true alloys are produced.

Another interesting fact is that metals, and probably all solids, evaporate at ordinary temperatures. It has long been known that ice evaporates very rapidly, and now it is

found that metals do the same, and the evaporation can be detected at temperatures far below their melting points. All these curious phenomena give us new ideas as to the constitution of matter, and lead us to the conclusion that the extreme mobility of the molecules of gases has its analogue in liquids and even in solids. The flow of metals, their diffusion into other metals, and their evaporation, lead to the conclusion that a proportion of their molecules must possess considerable mobility, and when these reach the surface they are enabled to escape either into other bodies in contact with them or into the atmosphere. This proportion of rapidly-moving molecules gives to solids some of the characteristics of liquids and of gases.

Before leaving this part of our subject we must refer to a most interesting and suggestive discovery which throws still further light on the constitution of matter and on the forces which give to matter many of the properties without which neither vegetable nor animal life would be possible. It has been found that all gases expand or contract equal amounts for every degree of heat, the amount being $\frac{1}{273}$ of their volume for each degree centigrade. Hence, beginning at zero, if a gas is cooled continuously down to $-273°$ C. or $-461°$ F., contraction would cease—that is, the gas would be reduced to a solid, and would cease to have the power of contraction. Hence this point is termed the absolute zero of temperature, and Lord Kelvin has arrived at the same result by quite different means. With the total absence of heat it is believed that all chemical action would cease, so that the universe would consist wholly of solid and chemically inert matter. Heat, therefore, seems to be the source of all change in matter and the essential condition of all life; while the other vibrations of the ether, which we know as light and electricity, may be also essential. Ether, therefore, appears to be the

active, matter the passive agent in the constitution of the universe; and the recognition of the existence of the ether, together with the considerable amount of knowledge we have acquired of its modes of action, must be held to constitute one of the most important intellectual triumphs of the nineteenth century.

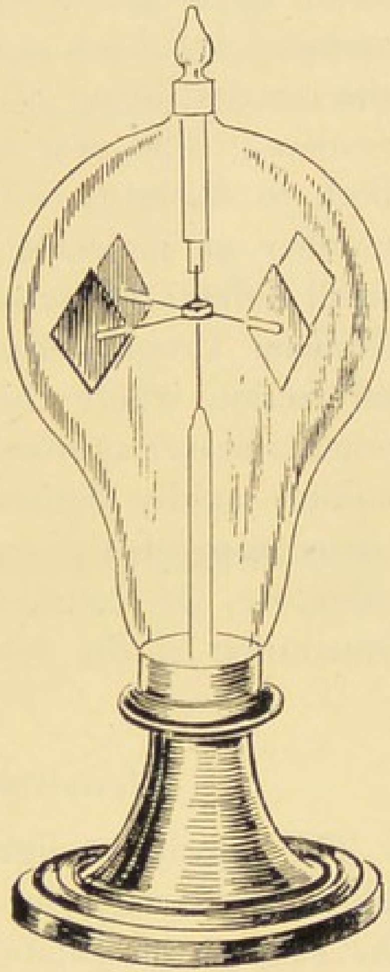


Fig. 61.—The Radiometer

The Radiometer

Among the very numerous discoveries depending upon physical principles, or on the application of physical laws, a few of the more generally interesting may be here noticed.

The radiometer, to be seen in almost every optician's window, was invented by Sir William Crookes in 1873, and consists of an exceedingly delicate windmill, formed of four very slender arms supporting thin metal or pith discs, one side of which is blackened, the whole turning on a fine central point, so as to revolve with hardly any friction. The little machine is enclosed in a glass bulb from which nearly all the air had been extracted; and when exposed to the sun, or even to diffused daylight, the discs revolve with considerable speed. At first this motion was supposed to be caused by the direct impact of the rays of light, the almost complete vacuum only serving to diminish friction; but the explanation now generally adopted is,

that the black surfaces of the vanes, absorbing heat, become slightly warmer than the white surfaces, and this greater warmth is communicated to the air-molecules, and causes them to rebound with greater rapidity from the dark surfaces and back again from the glass of the vessel, and the reaction being all in one direction, causes the arms to revolve. The near approach to a vacuum is necessary, both to diminish resistance, and by greatly reducing the number of molecules, in the vessel, to allow the very small differential action to produce a sensible effect. Sir William Crookes has found that there is a degree of rarefaction where the action is at a maximum, and that when a nearer approach to a perfect vacuum is attained the motion rapidly diminishes. A proof is thus given of the correctness of the explanation; and the instrument may, therefore, be considered to afford us an experimental illustration of the molecular theory of gases.

Measurement of the Velocity of Light

The velocity of light, as is well known, was first determined by Roemer in 1676, by irregularities in the time of the eclipses of Jupiter's satellites, which were found to occur earlier or later than the calculated times, according as we were near to, or far from, the planet. It was thus found that it required eight minutes for light to travel from the sun to the earth, a distance of a little more than 90,000,000 miles; so that light travels about 196,000 miles in a single second of time. As the exact mode of this measurement is not generally understood a short explanation will be given here. The eclipses of the satellites are not due to their being hid by the planet (which is termed an occultation) but by their passing through the shadow cast by the planet as shown in the accompanying diagram.

The light of the sun being thus cut off, the moment they enter the shadow they become invisible, and owing to the rapid motion of the satellites the time this occurs can be determined to less than a second, and will be the same from whatever direction the disappearance is observed which renders these eclipses so useful for determining longitudes at sea.

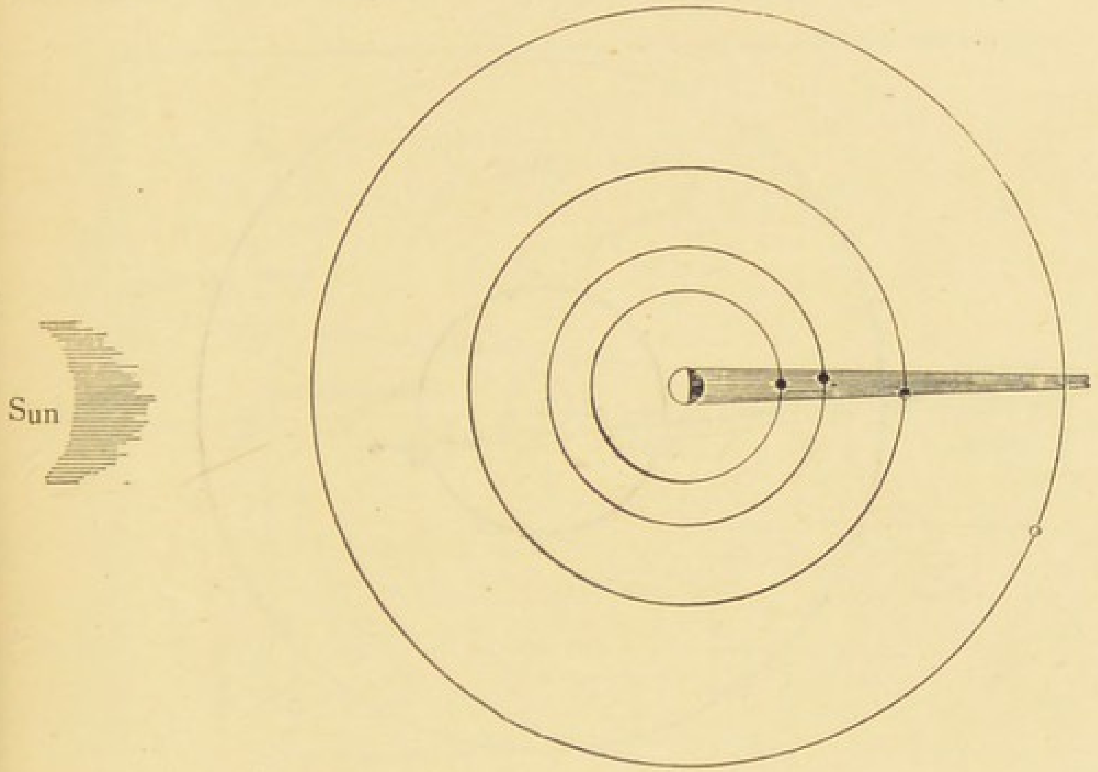


Fig. 62.—Eclipse of Jupiter's Satellites

Referring now to the next diagram (Fig. 63) we see that when the earth is nearest to the planet, at C., the light from Jupiter has to travel a much less distance than when we are farthest, at D., the difference being nearly 190,000,000 miles. The times when the eclipses should happen, having been calculated from the observations of the motions of the satellites for many years, should have been correct to a single second. And when it was found that the time was correct only twice a year (when the earth was at its mean distance from Jupiter), but that at all other times there was an error

gradually increasing till it amounted to eight minutes, and that this was always less than the calculated time when the earth was near, and more when it was distant from Jupiter, the conclusion that light required this time to pass from the planet to us was irresistible.

It was reserved, however, for the nineteenth century to demonstrate this explanation by an altogether new and un-

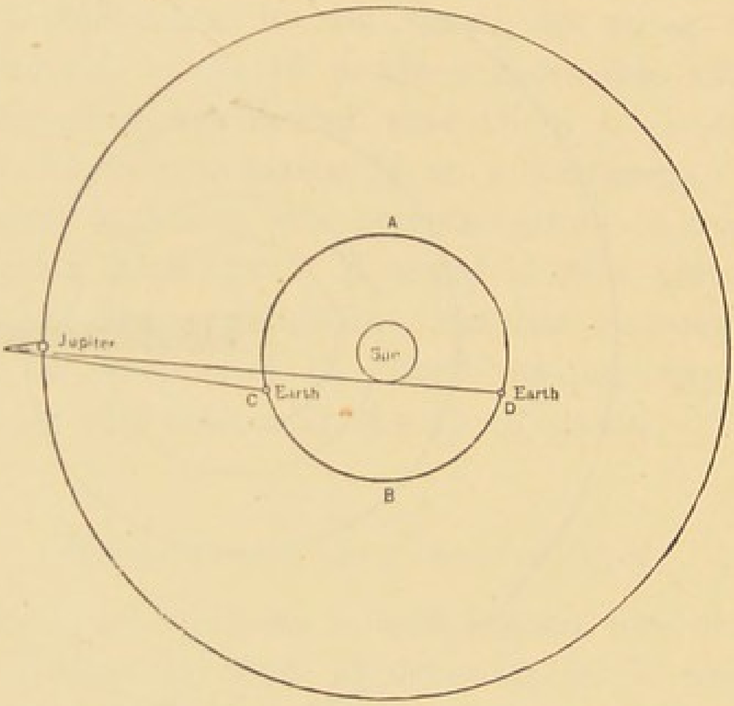


Fig. 63.—The Orbits of the Earth and of Jupiter

expected method. It would seem at first sight impossible to measure the time taken by light in travelling a mile, yet means have been discovered to do this and even to measure the time taken for light to traverse a few feet from one side of a room to the other. Yet more, this method of measuring the velocity of light has, by successive refinements, become so accurate that it is now considered to be the most satisfactory method of determining the mean distance of the sun from the earth, a distance which serves as the unit of measurement for the solar system and the whole stellar

universe. A brief account of how this is effected will now be given.

Fizeau, a French physicist, made the first attempt at measuring the velocity of light in 1849; and later, in 1862, in conjunction with Foucault, a more accurate determination was made by means of an apparatus of which the main features are given in the accompanying diagram. A ray of

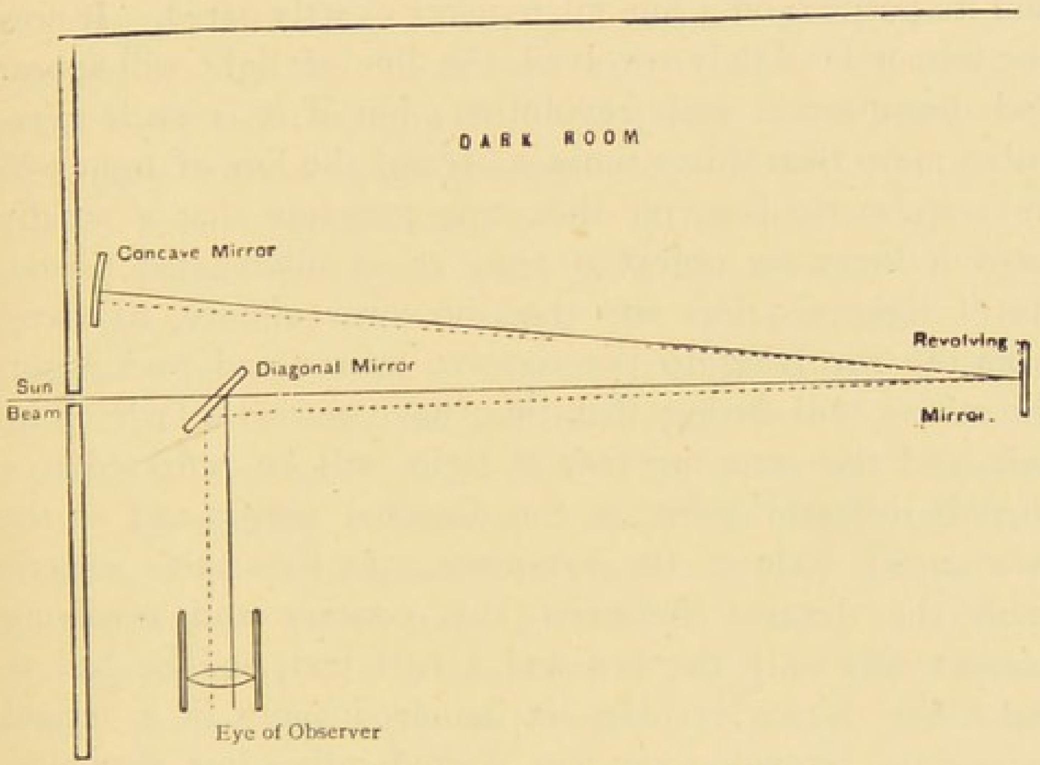


Fig. 64.—Measurement of Velocity of Light

sunlight is made to enter a darkened room by a narrow slit, and falls on a mirror at the farther side of the room, which can be made to revolve with great rapidity. From this it is reflected to a concave mirror having its centre of curvature at the revolving mirror. The diagonal mirror is transparent glass, through which the ray passes on its way to the revolving mirror, but on coming back a portion of the light is reflected at right angles to the eye of the observer. This involves much loss of light, and in more recent experiments the revolving mirror is slightly

tilted, so that the returning ray passes beneath the outgoing ray, and is then reflected by a mirror, or by a total-reflexion prism to the eye of the observer. Now let us suppose the revolving mirror to be at rest. The various mirrors are first accurately adjusted, so that the narrow slit of light (or a fine wire in its centre) is so reflected by the three mirrors that it can be seen in the observing eye-piece, and its position on a fine micrometer exactly noted. If now the mirror is slowly revolved, the line of light will appear and disappear at each revolution; but if it is made to revolve more than thirty times a second the line of light will be seen motionless, on the same principle that a rapidly moving luminous object is seen as an illuminated riband. But if light requires any time, however minute, to travel from the revolving to the concave mirror and back again, the mirror will during that time have turned a little on its axis, and the returning ray of light will be reflected to a slightly different point on the diagonal mirror and on the micrometer scale of the eye-piece. In Foucault's experiment the distance between the concave and revolving mirrors was only thirteen and a half feet, and he had to make the mirror revolve six hundred times in a second before the returning ray was shifted rather less than one-hundredth of an inch. By increasing the speed to eight hundred revolutions the distance was increased to about twelve-thousandths of an inch, which, under a powerful magnifier, could be measured with great precision. Having measured with great accuracy the distance between the mirrors, and knowing the exact number of revolutions a second of the mirror, which was shown by a simple clock-work connected with it, the velocity of light was deduced as being 185,157 miles per second.

It is evident that there are here several sources of error. The short distance traversed by the light renders it

necessary for the revolving mirror to turn with extreme rapidity, while the observed displacement of the ray is very small. Minute errors in the various measurements will, therefore, be enormously multiplied in the result. To obviate these difficulties, the concave mirror has been placed much farther away; and in the most recent and most accurate experiments by Professor Newcomb at Washington the distance between the revolving and the concave mirrors was about two and a half miles, and the mirror revolved two hundred and thirty times a second. This gave such a large displacement of the returning ray that it could be measured with extreme accuracy, and the average of numerous trials gave the velocity of light as 186,327 miles per second. It thus appears that Foucault's measurement in a small room was only in error about $\frac{1}{180}$, or a little more than a half of one per cent., a wonderful testimony to his skill as an experimenter under such unfavourable conditions. Professor Newcomb believes that his determination is correct within $\frac{1}{10000}$, but he thinks that by placing the mirrors twenty or thirty miles apart in the clear atmosphere of the Rocky Mountains a still greater approach to perfect accuracy could be obtained.*

Proof of Earth's Rotation

The same M. Leon Foucault who made these beautiful experiments on the measurement of the velocity of light has also discovered a method by which the rotation of the earth on its axis can be experimentally demonstrated. When a heavy body is in free motion in any direction it requires force to change the direction; and if no such

* For a more detailed account of Professor Newcomb's experiments, *see* "Nature," Vol. xxxiv. p. 170

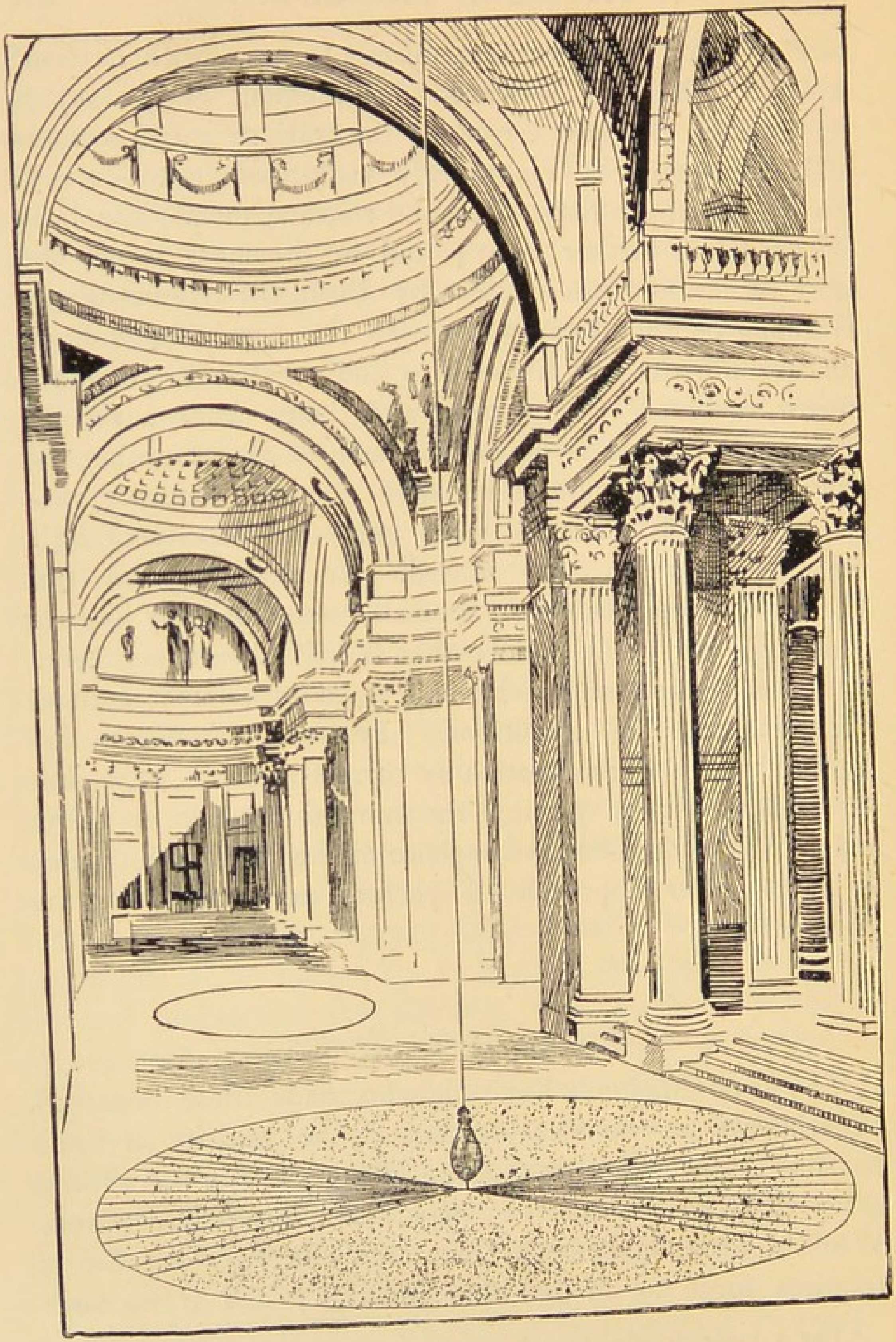


Fig. 65.—Foucault's Experiment to show the Earth's Rotation

force is applied, it will continue its motion in the same straight line or in the same plane. If a heavy pendulum is suspended from the axis of a horizontal wheel by a very long, thin wire, and if, when swinging in a fixed line across the room, the wheel is slowly turned, either the wire will twist a little or the ball forming the weight of the pendulum will revolve, but the plane in which the weight swings will not be altered. On the same principle, any pendulum freely swinging near the North Pole will not change the direction of its swing, although its point of support revolves in twenty-four hours with the earth's surface to which it is attached. On trying the experiment with a heavy weight suspended from the dome of the Panthéon in Paris and carefully set swinging, the plane of oscillation of the weight was found apparently to change at a uniform rate, and always in the same direction, which was opposite to that of the earth's rotation; proving that the surface of the earth moved round while the plane of oscillation remained fixed in space. This experiment can be tried in any place free from currents of air, such as a cellar. It only requires a heavy weight, say of 28 lbs., to be suspended by a string just strong enough to bear it. The weight must be drawn three or four feet away from the vertical line and fastened by a thread, so as to be set swinging by burning the thread without giving it any lateral motion. In an hour the line of swing will be found to have changed considerably, and in a direction opposite to that of the earth's rotation. At the North Pole a circle drawn on the surface turns completely round in twenty-four hours, so that a pendulum swung there with a circle beneath it divided like a twenty-four hour clock dial would appear to revolve, and would tell the time. At the Equator, however, a circle on the surface of the earth does not itself rotate on its centre as at the Pole, but is

merely carried round the earth with the north and south points of the circumference preserving the same direction in space. Therefore, at the Equator a pendulum should show no motion of rotation. At all intervening points it will appear to rotate, but slower and slower as we recede from the Pole; and mathematical calculation shows that, while at the Pole it apparently moves through an angle of 15° in an hour, at London it would move a little less than 12°, at Paris 11½°, at New York 9¾°, and at Ceylon somewhat less than 2° an hour. Experiments have been tried at each of these places, and the rate of apparent rotation of the pendulum has been found to agree very closely with the calculated amount, thus giving a complete proof that the apparent rotation is really due to the rotation to the earth on its axis. This mode of rendering the earth's rotation visible, in such a simple and convincing manner, is a discovery of considerable interest even among the many wonderful discoveries of the century.

The Phonograph

One more of these minor applications of scientific principles, leading to very startling results, must be briefly described. All sounds, including the infinitely varied modulations of the human voice, have long been known to be due to successive air-waves set up by various vibrating substances; but it would seem impossible by any mechanical means to reproduce these complex vibrations so exactly as to cause the words of the original speaker to be again heard, quite intelligibly, and with all their tones and modulations, at any distant time or place. Yet this has been done by means of the instrument called the phonograph, one of the many ingenious inventions of the American, Edison.

In the telephone this is effected instantaneously, through the medium of an electric current, which reproduces the vibrations set up by the voice of the speaker in a delicate elastic diaphragm by means of another diaphragm at the end of the conducting wire, perhaps hundreds of miles away, as already explained in Chapter IV. In the phonograph the whole operation is mechanical. A diaphragm is set vibrating by the voice as in the telephone, but instead of being reproduced at a distance by means of an electric current, it registers itself permanently on a cylinder of very

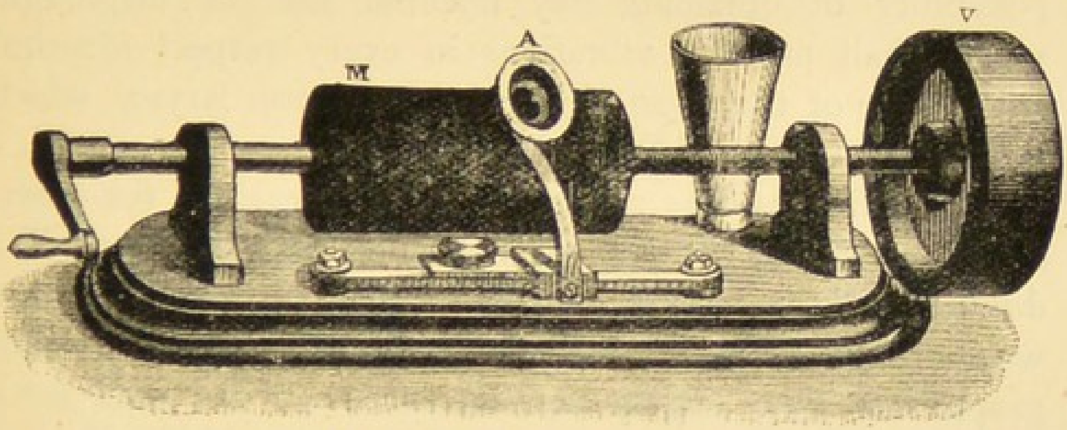


Fig. 66.—The Phonograph

hard wax, as an indented spiral line. This is effected by means of a fine steel point, like a graving tool, connected by a delicate lever with the centre of the diaphragm. The wax cylinder turns and travels onward at a perfectly uniform rate, which can be delicately adjusted, so that the steel point if stationary will cut in it a very fine spiral groove, uniform in depth from end to end, the turns of the groove being very close to each other. But when the diaphragm is set vibrating by the voice of the speaker, the steel point moves rapidly up and down, and the resulting groove continually varies in depth, forming a complex series of undulations. If now the cylinder is shifted back so that the steel point is exactly where it was at starting,

and the cylinder is then made to revolve and move onward at exactly the same rate as before, the up and down motions of the style, due to the irregular depth of the groove, set up the very same series of vibrations in the diaphragm as those which cut the groove; and these vibrations reproduce the voice with marvellous fidelity, so that the most complex and rapid speech or the most exquisite singing can be heard quite intelligibly, and with all their modulations and expressiveness, though not in exactly the same tone of voice. This difference of tone is due to the impossibility of obtaining any material for the diaphragm which shall produce vibrations in every respect identical with those of the vocal chords in the human larynx, which themselves vary in different individuals.

The cylinders thus produced can be preserved for years, can be carried to any part of the world, and by means of a duplicate of the original instrument will there reproduce the words and the vocal peculiarities of the speaker. Phonographs are now largely manufactured, and are used for a variety of purposes. They serve for the rapid dictation of correspondence, which can be reproduced and copied by a clerk later on; to take down discussions verbatim, with a perfection that no shorthand writer can rival; the singing or the elocution of celebrated performers is repeated for the gratification of friends or to amuse private parties; actors, musicians, and clergymen use the instrument as a means of improving their style; and even the languages, songs, and folk-lore of dying-out tribes are being preserved on these wonderful cylinders.

Probably there is no instrument in the world which so impresses the observer with the apparent inadequacy of the means to bring about so marvellous a result. At the same time it renders more mysterious than ever the properties and possibilities of air-waves and the extreme deli-

cacy of the ear and auditory nerves, which enable us instantaneously to interpret any one set of these vibrations amidst the many other sets of air-waves arising from various sources which must be continually crossing and intermingling in apparently inextricable confusion. The phonograph, whether as illustrating the ingenuity of man or the marvellous perfection of our organism, will certainly take high rank among the new inventions of the nineteenth century.

CHAPTER IX

THE IMPORTANCE OF DUST: A SOURCE OF BEAUTY AND ESSENTIAL TO LIFE

"When the lamp is shattered,
The light in the dust lies dead;
When the cloud is scattered,
The rainbow's glory is shed."
SHELLEY.

"How beautiful is the rain!
After the dust and heat,
In the broad and fiery street,
In the narrow lane,
How beautiful is the rain!"
LONGFELLOW.

THE majority of persons, if asked what were the uses of dust, would reply that they did not know it had any, but they were sure it was a great nuisance. It is true that dust in our town and in our houses is often not only a nuisance but a serious source of disease; while in many countries it produces ophthalmia, often resulting in total blindness. Dust, however, as it is usually perceived by us, is, like dirt, only matter in the wrong place, and whatever injuries or disagreeable effects it produces are largely due to our own dealings with nature. So soon as we dispense with horse-power and adopt purely mechanical means of traction and conveyance, we can almost wholly abolish disease-bearing dust from our streets and ultimately from all our highways; while another kind of dust, that caused by the imperfect combustion of coal, may be got rid of with equal facility so soon as we consider pure air,

sunlight, and natural beauty to be of more importance to the population as a whole than are the prejudices or the vested interests of those who produce the smoke.

But though we can thus minimise the dangers and the inconveniences arising from the grosser forms of dust, we cannot wholly abolish it; and it is, indeed, fortunate we cannot do so, since it has now been discovered that it is to the presence of dust we owe much of the beauty, and perhaps even the very habitability, of the earth we live upon. Few of the fairy tales of science are more marvellous than these recent discoveries as to the varied effects and important uses of dust in the economy of nature.

Why the Sky is blue

The question why the sky and the deep ocean are both blue did not much concern the earlier physicists. It was thought to be the natural colour of pure air and water, so pale as not to be visible when small quantities were seen, and only exhibiting its true tint when we looked through great depths of atmosphere or of oceanic water. But this theory did not explain the familiar facts of the gorgeous tints seen at sunset and sunrise not only in the atmosphere and on the clouds near the horizon, but also in equally resplendent hues when the invisible sun shines upon Alpine peaks and snowfields. A true theory should explain all these colours, which comprise almost every tint of the rainbow.

The explanation was found through experiments on the visibility or non-visibility of air which were made by the late Professor Tyndall about the year 1868. Everyone has seen the floating dust in a sunbeam when sunshine enters a partially-darkened room; but it is not generally known that if there was absolutely no dust in the air the

path of the sunbeam would be totally black and invisible, while if only very little dust was present in very minute particles the air would be as blue as a summer sky.

This was proved by passing a ray of electric light lengthways through a long glass cylinder filled with air of varying degrees of purity as regards dust. In the air of an ordinary room, however clean and well ventilated, the interior of the cylinder appears brilliantly illuminated. But if the cylinder is exhausted and then filled with air which has passed slowly through a fine gauze of intensely heated platinum wire, so as to burn up all the floating dust particles, which are mainly organic, the light will pass through the cylinder without illuminating the interior, which, viewed laterally, will appear as if filled with a dense black cloud. If, now, more air is passed into the cylinder through the heated gauze, but so rapidly that the dust particles are not wholly consumed, a slight blue haze will begin to appear, which will gradually become a pure blue, equal to that of a summer sky. If more and more dust particles are allowed to enter the blue becomes paler, and gradually changes to the colourless illumination of the ordinary air.

The explanation of these phenomena is that the number of dust-particles in ordinary air is so great that they reflect abundance of light of all wave-lengths, and thus cause the interior of the vessel containing them to appear illuminated with white light. The air which has passed slowly over white-hot platinum has had the dust particles destroyed, thus showing that they were almost wholly of organic origin, which is also indicated by their extreme lightness, causing them to float permanently in the atmosphere. The dust being thus got rid of, and pure air being entirely transparent, there is nothing in the cylinder to reflect the light which is sent through its centre in a beam of parallel rays so that none of it strikes against the sides, hence the inside

of the cylinder appears absolutely dark. But when all the larger dust particles are wholly or partially burnt, so that only the very smallest fragments remain, a blue light appears, because these are so minute as to reflect chiefly the more refrangible rays, which are of shorter wave-length—those at the blue end of the spectrum, which are thus scattered in all directions, while the red and yellow rays pass straight on as before.

We have seen that the air near the earth's surface is full of rather coarse particles which reflect all the rays, and which, therefore, produce no one colour. But higher up the particles necessarily become smaller and smaller, since the comparatively rare atmosphere will only support the very smallest and lightest. These exist throughout a great thickness of air, perhaps from one mile to ten miles high or even more, and blue or violet rays being reflected from the innumerable particles in this great mass of air, which is nearly uniform in all parts of the world as regards the presence of minute dust particles, produces the constant and nearly uniform tint we call sky-blue. A certain amount of white or yellow light is no doubt reflected from the coarser dust in the lower atmosphere, and slightly dilutes the blue and renders it not quite so deep and pure as it otherwise would be. This is shown by the increasing depth of the sky-colour when seen from the tops of lofty mountains, while from the still greater heights attained in balloons the sky appears of a blue-black colour, the blue reflected from the comparatively small amount of dust particles being seen against the intense black of stellar space. It is for the same reason that the "Italian skies" are of so rich a blue, because the Mediterranean sea on one side and the snowy Alps on the other do not furnish so large a quantity of atmospheric dust in the lower strata of air as in less favourably situated countries, thus leaving

the blue reflected by the more uniformly distributed fine dust of the higher strata undiluted. But these Mediterranean skies are surpassed by those of the central Pacific Ocean, where, owing to the small area of land, the lower atmosphere is more free from coarse dust than in any other part of the world.

If we look at the sky on a perfectly fine summer's day we shall find that the blue colour is the most pure and intense overhead and when looking high up in a direction opposite to the sun. Near the horizon it is always less bright, while in the region immediately round the sun it is more or less yellow. The reason of this is, that near the horizon we look through a very great thickness of the lower atmosphere, which is full of the larger dust-particles reflecting white light, and this dilutes the pure blue of the higher atmosphere seen beyond. And in the vicinity of the sun a good deal of the blue light is reflected back into space by the finer dust, thus giving a yellowish tinge to that which reaches us reflected chiefly from the coarse dust of the lower atmosphere. At sunset and sunrise, however, this last effect is greatly intensified, owing to the great thickness of the strata of air through which the light reaches us. The enormous amount of this dust is well shown by the fact that then only we can look full at the sun, even when the whole sky is free from clouds and there is no apparent mist. But the sun's rays then reach us after having passed first through an enormous thickness of the higher strata of the air, the minute dust of which reflects most of the blue rays away from us, leaving the complementary yellow light to pass on. Then the somewhat coarser dust reflects the green rays, leaving a more orange-coloured light to pass on; and finally some of the yellow is reflected, leaving almost pure red. But owing to the constant presence of air currents, arranging both the

dust and vapour in strata of varying extent and density, and of high or low clouds, which both absorb and reflect the light in varying degrees, we see produced all those wondrous combinations of tints and those gorgeous ever-changing colours, which are a constant source of admiration and delight to all who have the advantage of an uninterrupted view to the west, and who are accustomed to watch for these not unfrequent exhibitions of nature's kaleidoscopic colour-painting. With every change in the altitude of the sun the display changes its character; and most of all when it has sunk below the horizon, and, owing to the more favourable angles, a larger quantity of the coloured light is reflected towards us. Especially when there is a certain amount of cloud is this the case. These, so long as the sun was above the horizon, intercepted much of the light and colour; but when the great luminary has passed away from our direct vision, his light shines more directly on the under sides of all the clouds and air strata of different densities; a new and more brilliant light flushes the western sky, and a display of gorgeous ever-changing tints occurs, which is at once the delight of the beholder and the despair of the artist. And all this unsurpassable glory we owe to—dust!

A remarkable confirmation of this theory was given during the two or three years after the great eruption of Krakatoa, near Java. The volcanic debris was shot up from the crater many miles high, and the heavier portion of it fell upon the sea for several hundred miles around, and was found to be mainly composed of very thin flakes of volcanic glass. Much of this was, of course, ground to impalpable dust by the violence of the discharge, and was carried up to a height of many miles. Here it was caught by the return current of air continually flowing northwards and southwards above the equatorial zone; and as these

currents reach the temperate zone, where the surface rotation of the earth is less rapid, they continually flow eastward, and the fine dust was thus carried at a great altitude completely round the earth. Its effects were traced some months after the eruption in the appearance of brilliant sunset glows of an exceptional character, often flushing with crimson the whole western half of the visible sky. These glows continued in diminishing splendour for about three years; they were seen all over the temperate zone, and it was calculated that, before they finally disappeared, some of this fine dust must have travelled three times round the globe.

The blue Colour of liquid Oxygen

When oxygen gas was liquefied in considerable quantities it was found to have a deep blue colour, whereas liquid nitrogen was colourless. As might be expected, liquefied air is pale blue in colour by transmitted light—that is, it absorbs the red and yellow rays of the spectrum, allowing the blue to pass through. Many persons at once concluded that the blue colour of the sky was thus explained and that fine dust in the higher atmosphere had nothing to do with it.

This seems such a simple explanation that it has been adopted by at least one scientific writer, and some of my correspondents have pointed it out as being opposed to the dust theory. It will be well, therefore, to show that it does not affect the theory here set forth. In the first place, then, the blue colour of liquid oxygen will not account for the facts. Mr John Aitken, who has made atmospheric dust his special study, informs me that Professor Dewar has determined the relation between the colour of a substance in its liquid and gaseous states and that the law is as

follows:—The selective absorption of light (on which the colour depends) in different columns of a gas under different pressures is identical when the length multiplied into the square of the density is the same, and this law is true of all densities and also for the liquid state. It follows that the light blue of liquid air would be so attenuated in air at the earth's surface as to be quite imperceptible even in the whole depth of our atmosphere.

But there are also ample proofs that air is not perceptibly blue by transmitted light, which everyone can see for themselves. For if it were so, then every white object seen through about four miles of air near the earth's surface would appear sky-blue, because four miles of air at our average pressure roughly equals the amount in a vertical column of the whole height of the atmosphere. But white houses and sails and snow-covered hills at that distance do not appear the least blue, neither do the high cirrhus clouds nor the moon, and these facts demonstrate that the colour of the air is not that which causes the sky to appear blue. Moreover, if it *were* perceptibly blue, that would not make the sky blue; for if there were no solid matter in the atmosphere to reflect light, the sky would appear black however blue the air might be. If therefore the air *were* visibly blue—that is, absorbed the red and yellow rays and transmitted only those of the blue end of the spectrum—the only result would be that high clouds and mountains and the moon and the sun would all appear blue or bluish, while the sky would be always nearly as black as night—that is, a deep blue-black studded with stars. Hence both theory and observation assure us that the blue of the sky is *not* due to the colour of the air, and that whatever tinge of faint blue it may have is altogether imperceptible to our eyes.

The blue Colour of Seas and Lakes

The colour of our deep oceans and seas and of most of our great lakes affords a very interesting confirmation of the principles which have enabled us to explain the colour of the sky, but under a different set of conditions. It is a well-established fact that water itself, even when chemically pure, has a decided blue colour, which can be detected in rather small quantities, but which becomes a deep and pure blue when light is passed through it in a tube 20 feet or more in length. But although water is thus decidedly blue, yet our deep lakes and seas would not appear blue to us unless there were a large amount of solid matter dispersed through the water to reflect the light back to our eyes. To creatures *in* the water it would appear blue, to us looking on it from above it would be colourless or black.

This will be evident if we consider that light on entering water will be first refracted nearer to the perpendicular, and will then continue in straight lines till it reaches the bottom or strikes against some floating object on its way. But it has been proved that all the light is absorbed in passing through a few hundred feet of water, below which depth there is almost absolute darkness. Hence, if the water of the Mediterranean or of mid-ocean were free from all suspended solid matter or minute air-bubbles capable of reflecting light, we should perceive no blue colour but either white or coloured light reflected from the surface as by a mirror, or absolute blackness if we looked straight down into a shaded surface. And this is really what happens.

In 1870, Professor Tyndall had bottles of water sent him from the Mediterranean and from Lake Geneva, and on examining them at the Royal Institution by sending a

beam of electric light through them, he found that, when viewed laterally, the water appeared "distinctly blue," that from the Lake of Geneva being "especially rich and pure." This blue light was found to be polarised, showing that it was due to reflection of the blue rays by minute floating particles; and he adds: "In no respect could I discover that the blue of the water was different from that of the firmament. The colour presented by the Mediterranean water was a good sky-blue, while that presented by the Geneva water matched a sky of exceptional purity." He goes on to say that, although the presence of floating matter is of itself sufficient to produce the fine blue colour of seas and lakes, yet that there is a blue colour in water itself due to absorption of the red and yellow rays, leaving the blue to pass through. He then says: "Indeed, were it not for this, the light *transmitted* by a column of the water would be yellow, orange, or red"—that is, the blue being stopped and reflected by the floating particles, the remainder of the light would be from the yellow end of the spectrum. He thus implies that the transmitted light through water is really blue, though in this article he gives no experiments proving it.*

A much fuller investigation of this subject was made by Mr John Aitken, who published the results of his observations in 1882.† By means of a long metal tube to which variously-coloured objects were suspended at the lower end, he showed that white objects appeared of a deep and delicate blue at a depth of 20 feet. When coloured objects were used they became rapidly darker as the depth increased, showing that the yellow and red rays were absorbed by the water. Water was also examined in

* "Nature," Vol. ii. p. 489.

† "On the Colour of the Mediterranean and other Waters." Proc. of Roy. Soc. of Edinburgh, 1882, pp. 472-83.

dark horizontal tube with glass ends, and the colour by transmitted light was found to be blue. Similar results were obtained at the Italian lakes and the Lake of Geneva, while distilled water prepared in different ways and with great care was also found to be of a fine blue when the light passed through from 10 to 30 feet of it. Various spring and well waters were also examined, and were also found to be of various tints from blue to green.

These experiments clearly proved that water itself has a decided blue colour due to the absorption by its molecules of the red and yellow rays of the spectrum. But they also proved that the fine blue colour of seas and lakes which we see when looking at them from above could only be produced by some reflecting surfaces always present in water that exhibited this colour. This Tyndall had proved to exist in the bottles of water he examined, and Mr Aitken has shown that in every case where the water appears blue there is found to be a large number of white or whitish floating particles which reflect back the blue light that reaches them through the water, and that where the water is of the deepest blue it has less floating particles, but still sufficient to reflect the rays from moderate depths of perhaps 50 to 100 feet, the light from which depth will be the deepest blue due to the red and yellow rays having all been absorbed before that depth is reached, and also on account of the black background beyond.

Mr Aitken also made some experiments with coloured solutions which are exceedingly instructive. A solution of Prussian blue was placed in a vessel having dark sides and bottom so as not to reflect light upwards. Viewed from above the coloured solution appeared dark and colourless; but if a little fine white powder is thrown in then the solution at once becomes brightly coloured. By vary-

ing the amount of powder all the varied colour-effects of the Mediterranean can be reproduced, a little powder causing the solution to appear deep blue, and, as more and more powder is added, the colour changes to brighter blue, green-blue, and finally to chalky blue-green, as at places near the shore where there is much white sediment in the water.

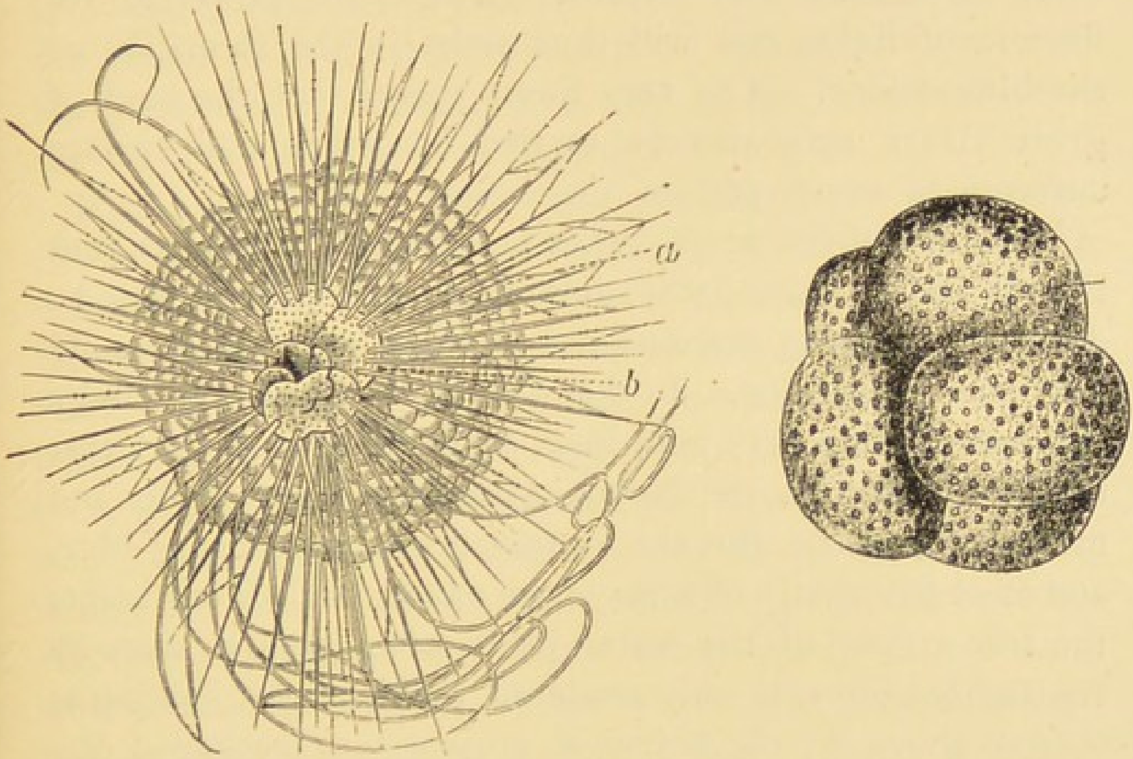


Fig. 67.—Examples of Organisms, the Shells of which constitute Deep-Sea Ooze. They are, roughly, the Size of Grains of Sea-Sand

The blue colour of the waters of the great oceans, even where most remote from land, indicates clearly that they must be everywhere pervaded with particles which reflect the light that would otherwise be lost in their depths. But in this case, a considerable portion of the effect is probably caused by minute living organisms which are known to abound in all the surface oceanic waters. We know, also, that volcanic and meteoric dust is constantly falling over the earth and ocean, and as the very finest

particles of this dust may take days or weeks to sink below the depth to which light penetrates, they may have a share in the production of the blue colour. Besides these solid particles there must always be a great quantity of minute air-bubbles in sea-water from the continued action of the waves, and owing to the continuous vertical circulation of the water these air particles must often be carried down to considerable depths. These are powerful reflectors of light, and will thus assist in the formation of the blue colour. The very finest particles of the mud of great rivers may also be carried by winds and surface currents to every part of the ocean.

The blue of the ocean varies in different regions as does that of the lakes, and the difference must in both cases be due to the varying amounts and local coloration of the solid matter in suspension. In the Atlantic between the tropics the water is of a very pure blue, somewhat lighter than that of the sky, but in the North Atlantic it has a duller and more indigo tint. But the universality of some tint of blue, and most frequently of a very pure azure, while it represents the true colour of the water itself when seen in mass by transmitted light, is only rendered visible to us, looking at it from above, by the universal presence of suspended particles of matter, inorganic or organic, dead or living, which abound everywhere in its superficial waters. Without dust in the air above us, the sky would appear black as at midnight. Without a corresponding aquatic dust, our seas and lakes and oceans would present to our eyes an almost equally gloomy aspect.

All the evidence goes to show, therefore, that the exquisite blue tints of sky and ocean, as well as all the sunset hues of sky and cloud, of mountain peak and alpine snows, are due to the finer particles of that very dust which, in its coarser forms, we find so annoying and even dangerous.

Dust as a Cloud and Rain-maker

But if this production of colour and beauty were the only useful function of dust, some persons might be disposed to dispense with it in order to escape its less agreeable effects. It has, however, been recently discovered that dust has another part to play in nature, a part so important that it is doubtful whether we could even live without it. To the presence of dust in the higher atmosphere we owe the formation of mists, clouds, and gentle beneficial rains, instead of waterspouts and destructive torrents.

It is barely thirty years since the discovery was made, first in France by Coulier and Mascart, but more thoroughly worked out by Mr John Aitken in 1880. He found that if a jet of steam is admitted into two large glass receivers, one filled with ordinary air the other with air which has been filtered through cotton-wool so as to keep back all particles of solid matter, the first will be instantly filled with condensed vapour in the usual cloudy form, while the other vessel will remain quite transparent. Another experiment was made more nearly reproducing what occurs in nature. Some water was placed in the two vessels prepared as before. When the water had evaporated sufficiently to saturate the air the vessels were slightly cooled, when a dense cloud was at once formed in the one, while the other remained quite clear. These experiments, and many others, showed that the mere cooling of vapour in air will not condense it into mist-clouds or rain unless *particles of solid matter* are present to form *nuclei* upon which condensation can begin. The density of the cloud is proportionate to the number of the particles; hence the fact that the steam issuing from the safety-valve or the chimney of a locomotive forms a dense white cloud shows that the air is really full of dust-particles, most of which

are microscopic, but none the less serving as centres of condensation for the vapour. Hence, if there were no dust in the air, escaping steam would remain invisible; there would be no clouds in the sky, and the vapour in the atmosphere, constantly accumulating through evaporation from seas and oceans and from the earth's surface, would have to find some other means of returning to its source.

One of these modes would be the deposition of dew, which is itself an illustration of the principle that vapour requires solid or liquid surfaces to condense upon; hence dew forms more readily and more abundantly on grass on account of the numerous centres of condensation it affords. Dew, however, is now formed only on clear cold nights after warm or moist days. The air near the surface is warm and contains much vapour, though below the point of saturation. But the innumerable points and extensive surfaces of grass radiate heat quickly and, becoming cool, lower the temperature of the adjacent air, which then reaches saturation point and condenses the contained vapour on the grass. Hence, if the atmosphere at the earth's surface became super-saturated with aqueous vapour, dew would be continuously deposited, especially on every form of vegetation, the result being that everything, including our clothing, would be constantly dripping wet. If there were absolutely no particles of solid matter in the upper atmosphere, all the moisture would be returned to the earth in the form of dense mists and frequent and copious dews, which in forests would form torrents of rain by the rapid condensation on the leaves. But if we suppose that solid particles were occasionally carried higher up through violent winds or tornadoes, then on those occasions the super-saturated atmosphere would condense rapidly upon them, and while falling would gather almost all the moisture in

the atmosphere in that locality, resulting in masses or sheets of water, which would be so ruinously destructive by the mere weight and impetus of their fall that it is doubtful whether they would not render the earth almost wholly uninhabitable.

The chief mode of discharging the atmospheric vapour in the absence of dust would, however, be by contact with the higher slopes of all mountain ranges. Aqueous vapour being lighter than air would accumulate in enormous quantities in the upper strata of the atmosphere, which would be always super-saturated and ready to condense upon any solid or liquid surfaces. But the quantity of land comprised in the upper half of all the mountains of the world is a very small fraction of the total surface of the globe, and this would lead to very disastrous results. The air in contact with the higher mountain slopes would rapidly discharge its water, which would run down the mountain sides in torrents. This condensation on every side of the mountains would leave a partial vacuum, which would set up currents from every direction to restore the equilibrium, thus bringing in more super-saturated air to suffer condensation and add its supply of water, again increasing the in-draught of more air. The result would be that winds would be constantly blowing towards every mountain range from all directions, keeping up the condensation and discharging, day and night and from one year's end to another, an amount of water equal to that which falls during the heaviest tropical rains. The whole of the rain that now falls over the entire surface of the earth and ocean, with the exception of a few desert areas, would then fall only on rather high mountains or steep, isolated hills, tearing down their sides in huge torrents, cutting deep ravines, and rendering all growth of vegetation impossible. The mountains would therefore be so devastated as to be uninhabit-

able, and would be equally incapable of supporting either vegetable or animal life.

But this constant condensation on the mountains would probably check the deposit on the lowlands in the form of dew, because the continual up-draught towards the higher slopes would withdraw almost the whole of the vapour as it rose from the oceans and other water-surfaces, and thus leave the lower strata over the plains almost or quite dry. And if this were the case there would be no vegetation, and therefore no animal life, on the plains and lowlands, which would thus become arid deserts cut through by the great rivers formed by the meeting together of the innumerable torrents from the mountains.

Now, although it may not be possible to determine with perfect accuracy what would happen under the supposed condition of the atmosphere, it is certain that the total absence of dust would so fundamentally change the meteorology of our globe as, not improbably, to render it uninhabitable by man and equally unsuitable for the larger portion of its existing animal and vegetable life.

Let us now briefly summarise what we owe to the universality of dust, and especially to that most finely divided portion of it which is constantly present in the atmosphere up to the height of many miles. First of all it gives us the pure blue of the sky, one of the most exquisitely beautiful colours in nature. It gives us also the glories of the sunset and the sunrise and all those brilliant hues seen in high mountain regions. Half the beauty of the world would vanish with the absence of dust. But, what is far more important than the colour of sky and beauty of sunset, dust gives us also diffused daylight, or skylight, that most equable and soothing and useful of all illuminating agencies. Without dust the sky would appear absolutely black, and the stars would be visible even at

noonday. The sky itself would therefore give us no light. We should have bright glaring sunlight and intensely dark shadows, with hardly any half-tones as faintly indicated in the accompanying illustrations (Figs. 68, 69). From this cause alone the world would be so totally different from what it is that all vegetable and animal life would probably have developed into very different forms, and even our own organisation would have been modified in order that we might enjoy life in a world of such harsh and violent contrasts.

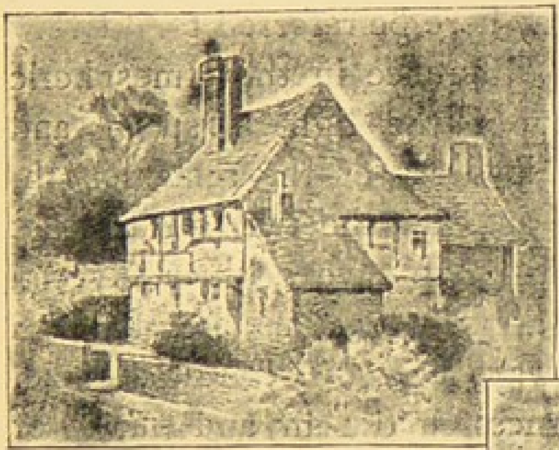


Fig. 68
With Dust—Soft Shadows

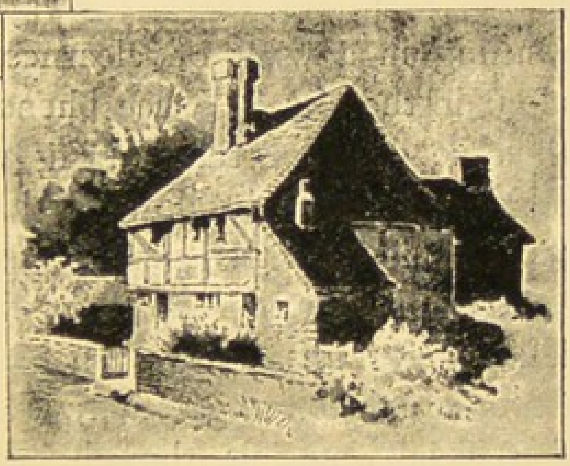


Fig. 69
Without Dust—Dark Shadows

In our houses we should have little light except when the sun shone directly into them, and even then every spot out of its direct rays would be completely dark except for light reflected from the walls. It would be necessary to have windows all round and the walls all white; and on the north side of every house a high white wall would have to be built to reflect the light and prevent that side from being in total darkness. Even then we should have to live in a perpetual glare, or shut out the sun altogether and use artificial light as being a far superior article,

Much more important would be the effects of a dust-free atmosphere in banishing clouds or mist or the "gentle rain of heaven," and in giving us in their place perpetual sunshine, desert lowlands, and mountains devastated by unceasing floods and raging torrents, so as, probably, to render life on the earth almost impossible.

There are a few other phenomena, apparently due to the same general causes, which may here be referred to. Every one must have noticed the difference in the atmospheric effects and general character of the light in spring and autumn, at times when the days are of the same length, and consequently when the sun has the same altitude at corresponding hours. In spring we have a bluer sky and greater transparency of the atmosphere; in autumn, even on very fine days, there is always a kind of yellowish haze, resulting in a want of clearness in the aïr and purity of colour in the sky. These phenomena are quite intelligible when we consider that during winter less dust is formed and more is brought down to the earth by rain and snow, resulting in the transparent atmosphere of spring, while exactly opposite conditions during summer bring about the mellow autumnal light. Again, the well-known beneficial effects of rain on vegetation, as compared with any amount of artificial watering, though, no doubt, largely due to the minute quantity of ammonia which the rain brings down with it from the air, must yet be partly derived from the organic or mineral particles which serve as the nuclei of every raindrop, and which, being so minute, are more readily dissolved in the soil and appropriated as nourishment by the roots of plants.

It will be observed that all these beneficial effects of dust are due to its presence in such quantities as are produced by natural causes, since both gentle showers as well as ample rains and deep blue skies are present throughout

the vast equatorial forest districts, where dust-forming agencies seem to be at a minimum. But in all densely-populated countries there is an enormous artificial production of dust—from our ploughed fields, from our roads and streets, where dust is continually formed by the iron-shod hoofs of innumerable horses, but chiefly from our enormous combustion of fuel pouring into the air volumes of smoke charged with unconsumed particles of carbon. This superabundance of dust, probably many times greater than that which would be produced under the more natural conditions which prevailed when our country was more thinly populated, must almost certainly produce some effect on our climate; and the particular effect it seems calculated to produce is the increase of cloud and fog, but not necessarily any increase of rain. Rain depends on the supply of aqueous vapour by evaporation; on temperature, which determines the dew point; and on changes in barometric pressure, which determine the winds. There is probably always and everywhere enough atmospheric dust to serve as centres of condensation at considerable altitudes, and thus to initiate rainfall when the other conditions are favourable; but the presence of increased quantities of dust at the lower levels must lead to the formation of denser clouds, although the minute water-vesicles cannot descend as rain, because, as they pass down into warmer and dryer strata of air, they are again evaporated.

Now, there is much evidence to show that there has been a considerable increase in the amount of cloud, and consequent decrease in the amount of sunshine, in all parts of our country. It is an undoubted fact that in the middle-ages England was a wine-producing country, and this implies more sunshine than we have now. Sunshine has a double effect, in heating the surface soil and thus causing more rapid growth, besides its direct effect in

ripening the fruit. This is well seen in Canada, where, notwithstanding a six months' winter of extreme severity, vines are grown as bushes in the open ground, and produce fruit equal to that of our ordinary greenhouses. Some years back, one of our gardening periodicals obtained from gardeners of forty or fifty years' experience a body of facts clearly indicating a comparatively recent change of climate. It was stated that in many parts of the country, especially in the north, fruits were formerly grown successfully and of good quality in gardens where they cannot be grown now; and this occurred in places sufficiently removed from manufacturing centres to be unaffected by any direct deleterious influence of smoke. But an increase of cloud, and consequent diminution of sunshine, would produce just such a result; and this increase is almost certain to have occurred, owing to the enormously increased amount of dust thrown into the atmosphere as our country has become more densely populated, and especially owing to the vast increase of our smoke-producing manufactories. It seems highly probable, therefore, that to increase the wealth of capitalist-manufacturers we are allowing the climate of our whole country to be greatly deteriorated in a way which diminishes both its productiveness and its beauty, thus injuriously affecting the enjoyment and the health of the whole population, since sunshine is itself an essential condition of healthy life. When this fact is thoroughly realised, we shall surely put a stop to such a reckless and wholly unnecessary production of injurious smoke and dust.

In conclusion, we find that the much-abused and all-pervading dust, which, when too freely produced, deteriorates our climate and brings us dirt, discomfort, and even disease, is, nevertheless, under natural conditions, an essential portion of the economy of nature. It gives

us much of the beauty of natural scenery as due to varying atmospheric effects of sky and cloud, and sunset tints, and thus renders life more enjoyable; while, as an essential condition of diffused daylight, and of moderate rainfalls combined with a dry atmosphere, it appears to be absolutely necessary for our existence upon the earth, perhaps even for the very development of terrestrial as opposed to aquatic life. The overwhelming importance of the small things, and even of the despised things of our world, has never, perhaps, been so strikingly brought home to us as in these recent investigations into the widespread and far-reaching beneficial influences of atmospheric dust.

CHAPTER X

SOME OF THE CHIEF PROBLEMS AND DISCOVERIES OF CHEMISTRY

"Force merges into force,
  The atom seeks its kind;
The elements are one,
  And each with all combined."
F. T. PALGRAVE.

"O Lavoisier, master great,
  We mourn your awful fate,
But never tire of singing to your praise.
  You laid foundations true,
  And we must trace to you
The chemistry of our enlightened days."
ANON.

THE science of modern chemistry has been created during the present century, but its phenomena and laws are so complex that it presents only a few of those great discoveries which are the starting-points for new developments, and which can, at the same time, be popularly described. The most important of all—that which constitutes the very foundation of chemistry as a science—is the law of chemical combination in multiple proportions, together with the atomic theory which serves to explain it.

The fact of chemical combination in definite proportions was suspected by some of the older chemists, but Dalton, in the early years of this century, was the first to establish it firmly as a general principle and to explain it by means of a comparatively simple theory. To illustrate by examples, it is found that the two gases, nitrogen and oxygen,

combine to form a variety of compounds, such as nitrous oxide or "laughing gas," nitric oxide, and several others. Nitrous oxide, or in chemical language, nitrogen monoxide,

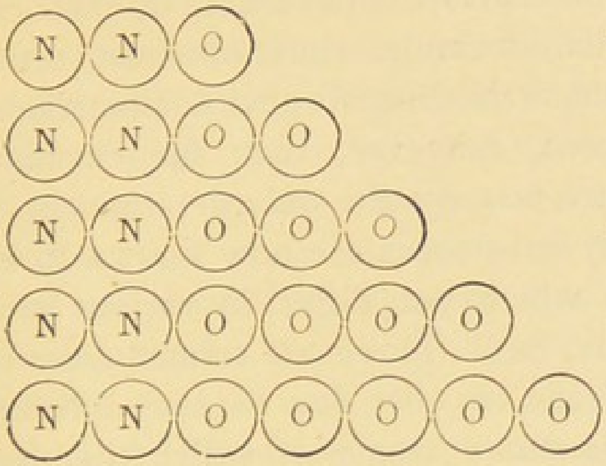
Fig. 70.—John Dalton, F.R.S.

consists of 28 parts by weight of nitrogen to 16 of oxygen, and all the other compounds of the same gases consist of two, three, four, or five times as much oxygen to the same quantity of nitrogen. Water consists of 16 parts oxygen to 2 of hydrogen, and there is another compound in which 32 parts oxygen combine with the same weight of

hydrogen, forming hydrogen dioxide or oxygenated water. This law applies to every chemical compound yet discovered, and as every element has a minimum proportionate weight, which can combine with any other element, these are called the atomic or combining weights of the elements. As the weight of the hydrogen in all its combinations is much less than the weight of the element it combines with, this gas is taken as the unit of measurement of atomic weights. Nitrogen is thus found to have an atomic weight of 14, oxygen 16, and chlorine 35. These are all gases; but many solids have much lower atomic weights, carbon being 12, and the rare metal beryllium only 9. Of other metals, that of aluminium is 27, copper 63, iron 56, silver 107, tin 117, and gold 196. There is thus no constant relation between the atomic weights and specific gravities of the elements in their solid state. Tin is a little lighter than iron, but has nearly double its atomic weight; gold has a high atomic weight, but bismuth has a higher still, although only half its specific gravity.

These facts are elucidated, and to some extent explained, by the atomic theory of Dalton. He supposed each element to consist of atoms, an atom being the smallest portion that has the properties of the element, and the atom of each element has a different weight. Hence, when one element combines with another the proportions must be either those represented by the atomic weights, or some multiple of those weights, since the atoms are assumed to be indivisible. This will be made clearer by another example. The atomic weights of nitrogen and oxygen are as 14 to 16, and these elements combine in five different proportions, as shown by the following figures, each circle representing an atom of the elements indicated by their initial letters;—

Chemical Symbol



=Nitrogen monoxide N_2O

=Nitrogen dioxide N_2O_2

=Nitrogen trioxide N_2O_3

=Nitrogen tetroxide N_2O_4

=Nitrogen pentoxide N_2O_5

The atomic or combining weights of all the elements having been carefully determined by numerous experiments, a beautiful system of chemical symbols has been formed, which greatly facilitates the study of the innumerable complex substances that have to be investigated. Each element is indicated either by one or two letters, being the initial letter, or some two characteristic letters, of its chemical name, so that nearly eighty elements are thus clearly defined. But these symbols represent not only the element but a definite proportional weight—the atomic weight. Thus H means a unit weight of hydrogen; C means 12 times that weight of carbon; Fe (ferrum) means 56 times that weight of iron. Hence the symbol for any compound substance tells us, in the most compact form possible, not only the elements of which it is composed, but the exact proportions in which these elements are combined. Thus C_2H_6O is the chemical symbol for pure alcohol, showing that it is a compound of two atoms of carbon, six of hydrogen, and one of oxygen. Looking now at a table of atomic weights, we find that this gives us 24 carbon, 6 hydrogen, and 16 oxygen in each 46 parts of alcohol. By means of these symbols and the accurate determination of atomic weights, all the complex combina-

tions and decompositions that occur during the investigations of the chemist can be represented in a kind of chemical algebra, and the peculiar formulæ thus obtained often suggest further experiments leading to new combinations.

It was soon discovered, however, that the chemical composition of a substance was not the only determinant of its properties, since many substances are now known to be identical in composition which yet differ in various properties, as density, colour, etc. These are termed cases of isomerism and are believed to be due to the different arrangement of the elementary atoms of which they are composed. The determination of these cases of isomerism and polymerism and their hypothetical explanation by the diverse arrangements of their constituent atoms form a special department of modern chemistry.

An additional complexity is introduced into this subject by the discovery that certain substances—as tartaric acid, for instance—crystallise into various forms, and some of these are irregular, having small facets on one corner only. Some, however, have the small facets on the right hand corner, others on the left hand, and these two kinds are found to have peculiar effects on polarised light, causing such rays to rotate in opposite directions. The study of these highly curious phenomena is termed stereo-chemistry; and it leads to many new conceptions as to the nature of atoms and their relations to the ether.

Affinities of the Elements

One of the most recent advances in the philosophy of chemistry is exhibited in the views of the Russian chemist, Mendeleef, as to the natural arrangement of the elements with certain deductions from it. The whole of the best-known elements form eight groups, placed in vertical

columns, depending on certain similarities in their powers of chemical combination. These are further arranged in twelve horizontal series, in which the atomic weights are most nearly alike, while increasing regularly from the first to the eighth group. In the table thus formed there are certain gaps in the regular order of increase of atomic weights, as if some elements were wanting; while in other cases the place of an element due to its atomic weight did not accord with that dependent on its chemical properties. But the general symmetry of the whole arrangement was such that Mendeleef predicted the future discovery of elements to fill the gaps, and named the chemical and physical properties of these unknown elements. In a few years three new elements were discovered—gallium, scandium, and germanium—and they precisely filled up three of the gaps in the system. Further research as to the atomic weights of the elements that did not fit into the scheme showed that errors had been made, that of uranium being much too low, while in the cases of gold, tellurium, and titanium it was too great. The remarkable success of these predictions—a success always considered the best proof of the truth of a theory—renders it almost certain that the true relations of the elements have now been approximately ascertained, while it strengthens the belief of those who think that what we term elements are not really so, but that their differences depend on special modes of aggregation of a few simple atoms, whose cohesion is so strong that we are not yet, and perhaps never shall be, able to overcome it.

Hardly less remarkable than these theories derived from the complex nature of modern researches are the numerous additions made to the known elements and the new conception as to the nature of the elements due to these discoveries. As many of these discoveries and conceptions

are of general interest, some account of them will now be given.

Discovery of New Elements

Quite early in the nineteenth century the new agency placed in the hands of chemists by the discoveries of Galvani and Volta in the preceding century began to bear fruit. In the year 1807 Sir Humphry Davy succeeded in decomposing potash and soda by means of the electric current, and discovered the two new metals potassium and sodium. He placed the potash and soda, which had hitherto been classed as elements, on an insulated platinum disc through which he passed an electric current, when the potash fused with a violent effervescence, and small metallic globules resembling quicksilver appeared—the new metal potassium. Later he produced sodium in the same way, and he also showed that various earths—lime, magnesia, etc. —were really oxides of metals, though he could not actually

Fig. 71.—Sir Humphry Davy

separate them, but this was done a little later by other chemists.

The most powerful agent in the discovery of new elements has been, however, the intense heat of the electrical arc combined with the marvellously delicate test afforded by the spectroscope, the principle of which has been explained in our seventh chapter.

Almost immediately after the discovery of spectrum analysis it led to the detection of two new metals—rubidium and cæsium—in the waters of some mineral springs; and later on to three others—thallium, indium, and gallium—in iron pyrites and zinc ores. Each of these is distinguished by a highly characteristic spectrum, thallium by a single line of a brilliant green, indium by a bright blue and a violet line, the others by an assemblage of brightly-coloured lines.

New Gases in the Atmosphere

Since the discovery of oxygen and nitrogen in the latter part of the eighteenth century the composition of the atmosphere as a mixture of those gases, with a small amount of carbonic acid and aqueous vapour, was believed to exhaust its possibilities as a chemical store-house. It seemed in the highest degree improbable that it should contain any hitherto undiscovered gaseous constituents. In 1895, however, Lord Rayleigh and Professor William Ramsay announced the discovery of a new gas which they named argon; and since then four others have been found having some common properties, which constitute them a special group of elements, to which the term "helium group" has been given.

The discovery arose from the fact that samples of nitrogen obtained from air differed in density from samples prepared from various nitrogen compounds, the former

being a little heavier. By elaborate and long-continued processes the heavier portion was separated, and was found to have different properties from nitrogen. It would not combine with any other element; when condensed into a liquid it was much heavier than liquid nitrogen; it had also a different boiling-point and freezing-point; and it was found to have a complex and peculiar spectrum, which was made up of two distinct spectra, in the one red in the other blue lines being predominant.

Helium had been first named in 1868 as the gas which produced some lines in the spectrum of the sun's chromosphere not due to any known terrestrial element. Not long after argon was discovered helium was found mixed with argon in cleveite, a rare Norwegian mineral. A few months later the two gases were found by Professor Ramsay in meteoric iron, and soon after in some mineral waters on the Continent; while helium has been found in gases given off by the Bath mineral waters.

In 1898 Professor Ramsay separated three other gases from the argon and helium of the atmosphere, and he thus briefly describes the process: "To separate these gases from each other they are compressed into a bulb, and cooled to $-185°$ C. ($= -301°$ F.) by being immersed in liquid air. The *argon*, *krypton*, and *xenon* condense to a liquid in which the *xeon* and *helium* are dissolved. On removing the bulb from the liquid air its temperature rises, and the helium and neon escape first, mixed with a large amount of argon. Argon distils next, and krypton and xenon remain till the last. By frequently repeating this process of fractional distillation, the argon, krypton, and xenon can be separated from each other and from the helium and neon which still remain mixed with each other, for both are gases at the temperature of boiling air." To separate helium from neon recourse must be had to liquid hydrogen (the production of which

has been described in Chapter VII.). By its aid, if a mixture of neon and helium is cooled to $-240°$ C. ($= -400°$ F.), the former freezes while the latter remains gaseous. The gaseous helium can then be collected, and the neon, with a slightly higher temperature, remains in a gaseous state.

These five elementary gases together constitute less than one per cent. of atmospheric air, and the fact that they differ so little in density from nitrogen, have no peculiar smell, and appear to be quite inert—that is, form no chemi-combinations with other bodies, will account for their having remained so long undetected by the chemical researches of the whole world. Argon, which was the first discovered, is by far the most abundant, being in the proportion of 400 to 1 of the other four; so that, if these are in equal quantities, each will form less than the 100,000th part of any given quantity of air. The discovery of these new and unexpected elements in the air we breathe, and the determination of their densities, their freezing and boiling points, and their characteristic spectra, together with the fact that one of them was first detected in the sun's chromosphere, constitute one of the scientific triumphs of the last decade of the nineteenth century.*

The Elements as studied by Spectrum Analysis

Both chemists and astronomers make so much use of spectrum analysis that many of the latter have found it necessary to study the spectra of the elements in the laboratory, under various conditions of temperature and pressure, in order better to understand the spectra of the

* This account of the new gases is derived from the Royal Society paper of Lord Rayleigh and Professor Ramsay, from numerous letters and papers in *Nature* (1895-8), and from Professor Ramsay's "Primer of Chemistry" (1900).

sun, stars, and nebulæ, and this study has led to some startling conclusions as to the nature of the elements. A few of the more interesting results will here be noted.

The first fact of importance is that many compound bodies exhibit special spectra up to a certain temperature; but with greater heat they become decomposed, and the spectra of their elements begin to show themselves. Now many of the reputed elements present what seem to be analogous phenomena. Thus, iron at increasing temperature gives four distinct spectra: (1) At the heat of a Bunsen gas flame it has a spectrum of a few lines and flutings; (2) the spectrum shown in the electric arc has over 2000 lines; (3) the still greater heat of the electric spark gives a similar spectrum, but with some lines of greater and some of less brilliancy; (4) the greatest heat attainable, by a spark several feet long, gives a spectrum with very few but very intense lines. Several other elements exhibit analogous phenomena; and in different stars the lines indicating the same elements undergo similar changes of intensity. Hence it is concluded that the stars have different temperatures.

Series of Spectral Lines

The spectra of many of the elements exhibit a number of lines which, on examination, can be arranged in two or more *series*, each series consisting of lines at decreasing distances from each other as they approach the violet end of the spectrum, and the decrease is found to be in accordance with a mathematical formula. When the lines are very numerous they produce an effect of hollowed curves and are then termed flutings. (*See* Fig. 73.) Oxygen has six series; hydrogen three; sodium, sulphur, and selenium three; calcium, mercury, zinc, and some others two; rubidium and cæsium only one.

These rhythmical series of spectral lines seem to imply one form of molecule for each series, and when there are

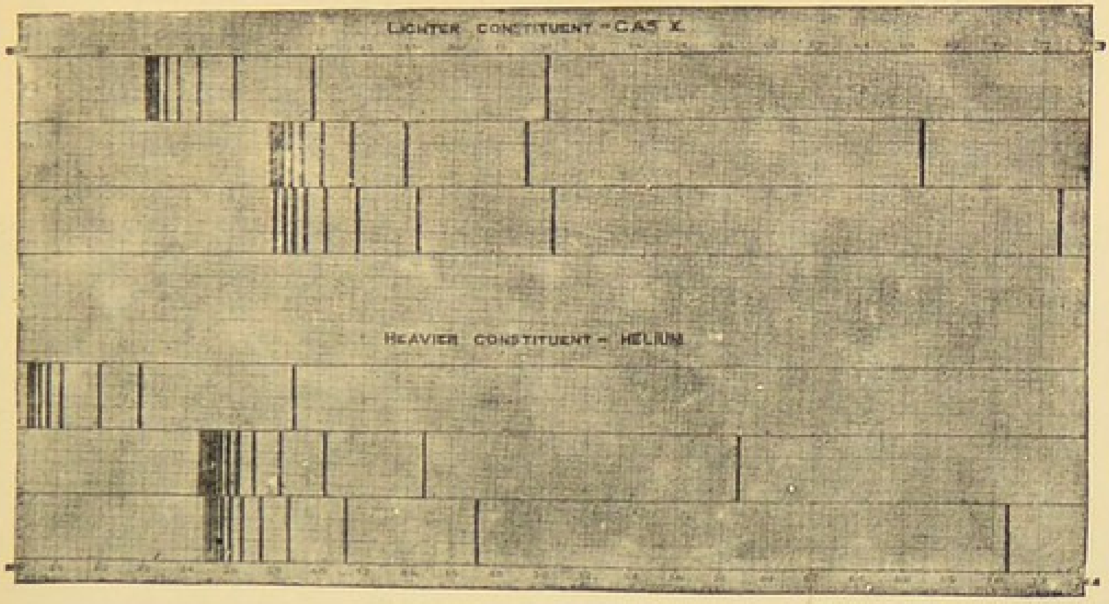


Fig. 72.—Series of Lines in Helium and Allied Gases
(From Lockyer's "Inorganic Evolution")

two, three, or more such series in the spectrum of any element it implies that we have to deal with a compound of distinct molecules rather than with a true element. Most of the metals with high melting-points—gold, tin,

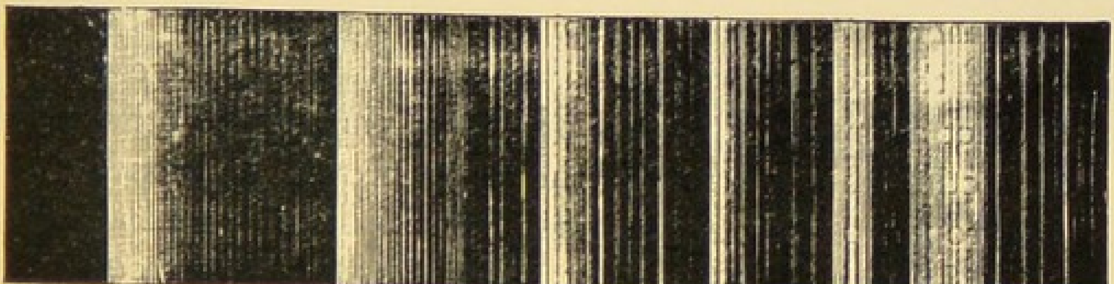


Fig. 73.—Spectral Lines forming Flutings
(From Lockyer's "Inorganic Evolution")

aluminium, cadmium, etc.—show no distinct series of lines. Some chemists have already expressed the opinion that the so-called elements often consist of very complicated systems

of atoms, and when their spectra become less complex under the action of intense heat it probably indicates a resolution into unknown simpler elements.* Commenting on these investigations of Sir N. Lockyer, Mr Preston says: "These observations lend some support to the ideas, so long entertained merely as a speculation, that all the various kinds of matter, all the various so-called chemical elements, may be built up in some way of the same fundamental substance."

New Elements discovered by Fractionation

Fractionation is a special method of chemical research by which elements which differ very slightly in their chemical or physical properties may be separated from each other. For example, when a substance in solution is precipitated, and it is suspected that the precipitate may contain two or more elementary substances very similar to each other, a minute quantity of the re-agent is used so as to render the process of precipitation a very slow one. It is to be presumed that if there are really two elements in the solution one will be precipitated somewhat more rapidly than the other. Then, by stopping the process when half or less of the total amount is precipitated we shall have in the product a larger proportion of one (*a*) than of the other (*b*). Subjecting this portion to the same process a second time the proportion of (*a*) will increase till by continual repetitions of the process (*a*) is obtained almost or quite free from (*b*). The remainder being treated in the same way more (*a*) will be obtained, till at last the remaining solution will contain only pure (*b*) without any admixture of (*a*).

* The facts here given have been gleaned from Sir Norman Lockyer's account of his own researches, and those of other students, in his recent work on "Inorganic Evolution."

By a process of this nature Sir William Crookes has obtained five distinct substances from the earth: yttria (the oxide of the supposed element yttrium). Each of these gives a distinct spectrum, different from that of yttrium though allied to it. (*See* Fig. 74.) They are characterised by differently-coloured phosphorescent lines or bands of

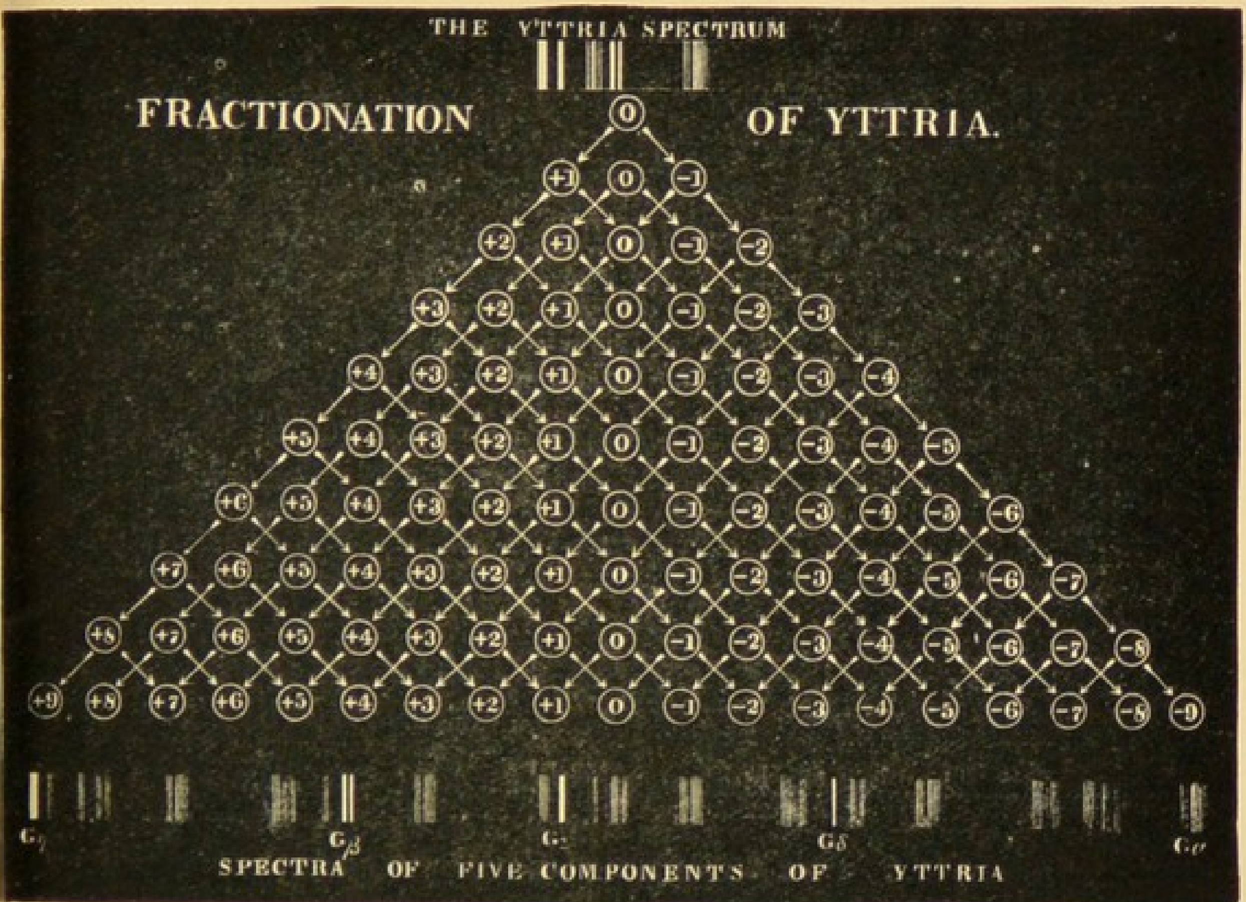


Fig. 74.—From Lockyer's "Inorganic Evolution"

different wave-lengths, and may perhaps indicate five different elements formed by splitting up the yttrium molecule into its constituents. These new substances have been provisionally termed meta-elements.

Other methods of fractionation are by crystallisation, or by the liquefaction and distillation of gases, as already described in the account of the new gases in the atmosphere.

This process is often an exceedingly laborious and tedious one, and the experiments may be continued for months or years before attaining a satisfactory result.

A New Common Metal

Among the useful practical discoveries of a chemical nature a very important one is the method of making the formerly rare metal aluminium in large quantities. The ancients were acquainted with only seven metals—gold, silver, copper, iron, tin, lead, and mercury; and these seven still remain the most common and most generally useful metals. Zinc, and perhaps nickel, were also used in early times in the form of alloys, but were not known as separate metals. Although we are now acquainted with more than fifty metals, most of which were discovered in the nineteenth century, yet, till quite recently, we had made no additions to those common and useful metals which were known to the civilised nations of antiquity, and in proportion to their requirements were as commonly used by them as by us. But in aluminium we have a metal whose peculiar properties render it suitable for many purposes to a greater extent than any other metal. It has the admirable quality of not being tarnished by air or water, and must thus be ranked among the "noble" metals—gold, platinum, and silver. It is malleable and ductile, and when hammered or drawn out into wire becomes almost as strong as iron. Combined with these excellent qualities it possesses one which is unique among the more stable and useful metals—its extreme lightness. It is lighter than glass, and only about one-third the weight of tin—the lightest of all the common and older metals—and thus becomes specially adapted for many domestic and scientific uses.

The strange thing is that this beautiful and useful metal, whose very existence only became known to us in 1828 abounds everywhere in enormous quantities in the form of clay, of which it forms the chemical base. It may possibly be the most abundant of all metals, yet it was only within the last quarter of the nineteenth century that a mode of separating it from this common substance was discovered. By improved processes it has been manufactured in larger quantities, and is now less than half the price of silver, but, being so much lighter and stronger, it is practically not one fourth the price; and as its uses increase, and it is made on a larger scale, it will probably soon be as cheap as copper or tin.

In this metal, therefore, we have another of those instances in which the discoveries of the nineteenth century have formed a new departure from those of all the preceding centuries of civilisation. We have discovered a new common metal—a metal which is calculated to rank with the most useful of any yet known, and whose remarkable properties lend themselves to a wider extention of economic applications of which we have at present little conception. The discovery of such a metal, and the bringing it so quickly into the service of man, may well rank as one of the notable achievements of the nineteenth century.

This very brief sketch of a few of the points of popular interest in the chemistry of the past century gives no adequate idea of the wonderful range of its subject-matter nor of the excessively intricate nature of the phenomena with which it deals. There is no physical science, except perhaps electricity, the facts and laws of which are at once so complex and so far removed from the perceptions or comprehension of the educated but unscientific reader. It is therefore impossible to render them popular or even intelligible to those who have not already studied the

subject. A few of its practical results may, however, be referred to.

The highly complex constitution of various organic products—albumen, fat, gums, resins, acids, oils, ethers, etc.—is the subject of organic chemistry, the study of which has led to some of the most popularly interesting discoveries. Coal-tar has furnished us with a wonderful series of colouring matters, such as the aniline and other dyes, while from the same material are produced benzol, carbolic acid, creosote, artificial musk, and saccharine, a substitute for sugar. The new explosives, such as dynamite and nitro-glycerine, are produced from animal or vegetable fatty matters; while some of the greatest triumphs of the modern chemist are the artificial production of natural substances which were long supposed to be due to organic processes alone. Such are the dye, indigo, citric acid, urea, and many others, including many of the various sugars which had hitherto been only obtainable from different plants.*

* As these discoveries are very interesting, and few who are not chemists are aware how numerous they are, I have asked my friend Professor Raphael Meldola, F.R.S., to furnish me with a list of the more important of them, which he has been kind enough to do as follows:—

Synthetical Achievements in Organic Chemistry

About 200 definite chemical compounds of vegetable and animal origin have been prepared by laboratory methods quite independently of the living organism.

Among the more remarkable are:

Cymene, a constituent of Roman cumin oil.
Ethyl alcohol, a product of fermentation of sugars by yeast.
Geraniol, a constituent of the oil of Indian geranium, citronella oil, and other fragrant ethereal plant oils.
Glycerol (or glycerin), the basis of most natural fats and saponifiable oils.
Mannite, a constituent of the vegetable exudation "manna."
Sorbite, found in berries of mountain ash.
Carvacrol, found in oil of carraway-seed, etc. etc.
Thymol, from oil of thyme.
Methylengenol, in the oil from paracoto bark, Bolivia.

In estimating the achievements of chemistry, however, it must always be remembered that some of the most popular discoveries of the century, which have been discussed in our earlier chapters, are really the product of scientific chemistry. Such are—friction matches, gas-

Antiarol, sap of the upas-tree, *Antiaris toxicaria.*
Hydrojuglone, in all green parts of the walnut-tree.
Citral, the chief constituent of lemon-grass oil, *Andropogon citratus.*
Methylnonyl-ketone, the chief constituent of oil of rue.
Benzoic aldehyde, oil of bitter almond.
Salicylic aldehyde, oil of *Spiræa ulmaria* (flowers).
Vanillin, the fragrant principle of the vanilla bean.
Cinnamic aldehyde, oils of cinnamon and cassia.
Menthol, oil of peppermint.
Gentisin, yellow colouring-matter from root of *Gentiana lutea.*
Chrysin, yellow colouring-matter from buds of poplar.
Luteolin, colouring-matter from *Reseda luteola.*
Alizarin and Purpurin, colouring-matters of madder root.
The *Sugars*, grape sugar (dextrose or glucose) and fruit sugar (lævulose).
Salicin, the crystalline glucoside from willow bark.
Allyl, Benzyl, and many other mustard oils.
Formic Acid, defensive secretion of ants, larva of puss-moth, etc.
Stearic and Palmitic Acids, found in many vegetable saponifiable oils.
Lactic Acid, acid of sour milk (bacterial product).
Oxalic Acid, in juices of many plants.
Malic Acid, in juices of apples, pears, and many other fruits.
Tartaric Acid, the acid of grape juice.
Citric Acid, the acid of lemon, lime, orange, etc. juice.
Benzoic Acid, gum benzoin.
Hippuric Acid, urine of herbivorous mammals.
Cinnamic Acid, oil of cinnamon.
Salicylic Acid, oil of wintergreen (*Gaultheria*) as methyl ether.
Tyrosin, bacterial putrefaction of albuminous substances.
Indigo, colouring-matter of *Indigofera* and *Isatis.*
Coumarin, fragrant principle of tonquin bean, *Dipteryx odorata.*
Piperic Acid, from black pepper.
Gallic Acid, acid of oak and other galls.
Neurine, Putrescine, and Cadaverine, bases resulting from bacterial putrefaction of animal matters.
Choline, in juices of many growing plants.
Urea, Creatine, and Creatinine, basic constituents of mammalian urine.
Uric Acid, acid constituent of urine.
Caffeine and Theophylline, alkaloids from coffee and tea.
Theobromine, alkaloid of cocoa.
Asparagin, in growing shoots of green plants generally.
Coniine, alkaloid of hemlock.
Arecoline, alkaloid of *Areca catechu* nut.

illumination, and all the wonders of photography; so that even in its application to the needs of our daily life, as well as in the light it has thrown on some of the great problems of the universe, it will be seen that chemistry has contributed its full share to the scientific triumphs of the nineteenth century.

CHAPTER XI

ELECTRICITY: THE SCIENCE OF THE CENTURY

"Mysterious force, that throbs from sun to sun,
Whose pulses vibrate through earth, air, and sea,
Flashing our speech to far Antipodes."
ANON.

OF the various branches of human knowledge which have at once opened new vistas into the mysteries of the universe and furnished new and unexpected, and still unexhausted powers for the service of mankind, none can surpass, perhaps none can even approach, the science of electricity. Most of its applications have been referred to in previous chapters, but its great importance seems to render necessary a short sketch of its early history and a very brief statement of such portions of its theory and principles as can be made generally intelligible.

Early History of Electricity

Considering what we now know of the universality and omnipresence of electricity in some of its] protean manifestations, it is strange how little was known of it, and how isolated and trivial it seemed to be, during the many thousand years of man's intellectual growth down almost to modern times. The Greeks and Romans, and the whole of the thinking world down to the year 1600, knew only one fact connected with electricity proper—that two substances—amber and jet—when rubbed will attract light particles such as chaff, dust, etc. This was

a curious, isolated fact, but apparently too trivial to be further inquired into. One other isolated fact they knew also, the existence of certain black stones which attracted iron just as the amber attracted chaff. This was the magnet-stone or lodestone, and its power was thought to be magical. It was known at some earlier period that by rubbing pieces of iron with a magnet they became possessed of its attractive properties, but it was not till the year 1300 that Flavio Gioja discovered the power possessed by a magnetised needle or iron bar when floating on water or when suspended by a thread, of pointing to the north, a power quickly utilised as the mariner's compass. These three apparently unconnected facts were all the indications recognised by mankind of one of the most widespread, most subtle, and perhaps most important of the forces of nature, till three hundred years later, when an English physician, Dr Gilbert of Colchester, for the first time in the history of the world began seriously to study them.

He defined the poles of magnets and imputed the direction of the magnetic needle to the magnetic power of the earth. He also discovered that many other substances besides amber were capable of exhibiting the same attractive properties when rubbed. In his volume, "De Magnete," published in the year 1600, he indicated how the magnetic force might be measured. He also had globes made of "lodestone," and showed that both the declination and dip of the magnetic needle were produced on a small scale by these globes, and in various other ways investigated the simpler laws of magnetism and electricity. He gave the name "electrics" to those substances which exhibit its phenomena when rubbed; and, most important of all, he suggested that the phenomena both of magnets and electrics are but different manifestations of the same

natural force. He must, therefore, be considered to be the founder of the science of electricity.

No further progress appears to have been made till the eighteenth century, when several persons again paid attention to the phenomena, and machines for producing electricity by friction were first made. But the man who did most towards a comprehension of the phenomena was Benjamin Franklin, who, as the result of his experiments, came to the conclusion that the electric force or fluid, as it was then supposed to be, was not created by rubbing, as had been hitherto supposed, but that all substances whatever contained it, and that friction merely concentrated in one body what was drawn out of another, and thus produced inequality in its distribution. When two bodies in which it is thus unequally distributed came into contact, the electricity passed from one to the other, restoring the equilibrium, the process causing a shock or spark. On this view he originated the terms *negative* and *positive* electricity, which are still in use, although the exact meaning that should be given them is even now uncertain.

Franklin's great practical discovery was to prove by direct experiment, in 1749, that lightning was simply an electric spark on a gigantic scale, and to suggest that by suitably arranged conductors the electricity could be drawn from the clouds to the earth and thus prevent houses from being struck by lightning.

The next great step was made a few years later by Volta, an Italian professor, who, when repeating the experiments of Galvani on the electric contraction of frogs' legs, discovered what is now termed "current-electricity," by means of the "voltaic pile" or "battery," which, under endless modifications, is still in use for the production of electric currents for various purposes.

Electricity at the Dawn of the Century

We are now brought to the beginning of the nineteenth century, with an elementary knowledge of three forms of electricity as manifested (1) in the ordinary friction-machine and the powerful charges that can be accumulated in the Leyden-jar; (2) in the various forms of the voltaic battery with its constant currents; and (3) in the phenomena of magnets and the earth's magnetism. The identity of the forces at work in the two first had been proved, but magnetism still remained as an unconnected but probably allied force. The next great step was the demonstration of their identity.

Magnetism and Electricity

Although the fact that lightning sometimes magnetised knives and other pieces of steel had been occasionally observed, all attempts to produce the same effects by electricity had failed. The first real step to a knowledge of the true relations of these forces was made by Professor Œrsted of Copenhagen in 1819. When making observations with voltaic piles and batteries he found that a magnetic needle, which happened to be near one of the wires carrying the electric current, began to vibrate. Seeing the immense importance of this he carefully experimented for several months, and at length proved that when an electric current passes near a magnetic needle the needle will turn so *as to lie across the direction of the current.* Further, if the wire is above the needle it will turn one way, and if below it the opposite way, and it will also change its direction if the direction of the current is changed. The diagram (Fig. 75) will illustrate the law

of these changes. It shows the needle pointing to north and south, a current passes *over* it from north to south, and the needle will be turned with its north pole towards the east. If the wire is held *below* the needle, *or*, if the direction of the current is changed, the needle will be turned with its north pole towards the west. If both changes are made at once no change is produced in the direction of the rotation of the needle; and this is very important, because it allows a current to pass round and round a needle or magnetised bar of iron in a dense coil,

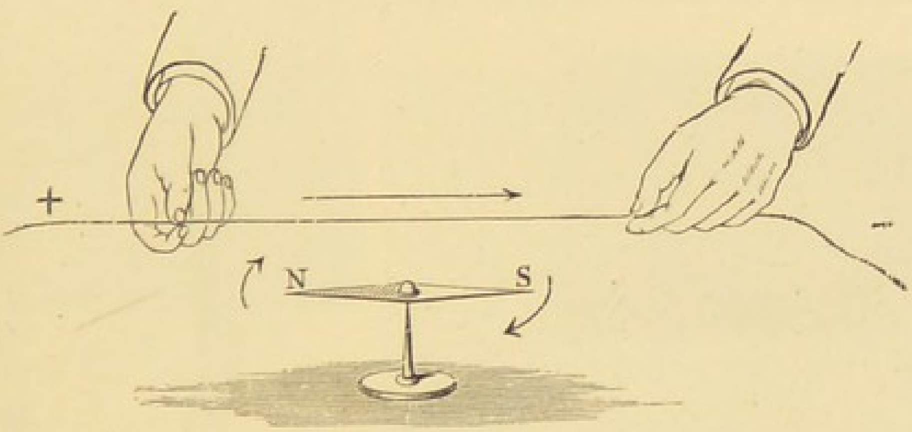


Fig. 75.—Œrsted's Experiment

and thus indefinitely increase the turning power of the needle or magnet, and it is this turning power which is used in modern electric motors.

Electro-magnets

Soon afterwards, Ampère, in Paris, found that bars of soft iron became temporary magnets if an electrical current were passed round them through a coil of copper wire. In this way far more powerful magnets can be made than in the ordinary way, and by using steel instead of iron more permanent magnets can be formed. The complete proof was thus given that magnetism is due to electric currents;

but the experiment was much more important by affording a means of rapidly making and unmaking powerful magnets. These electro-magnets form an essential part of the dynamo-electric machines now used in many of the applications of electrical forces.

Magneto-Electric Induction

The next important discovery was that of Faraday in 1831. He found that electric currents can be induced in a closed

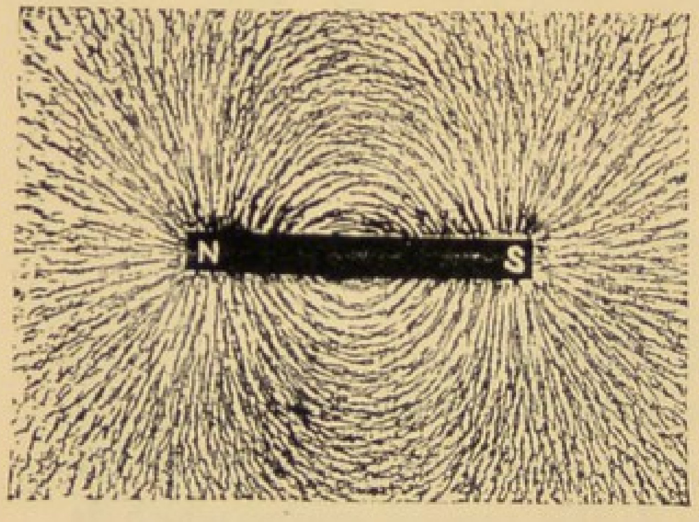


Fig. 76.—Bar Magnet and Iron Filings

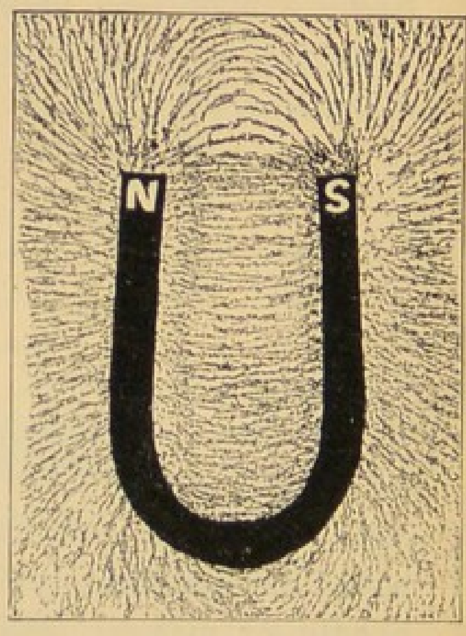


Fig. 77.—Horse-shoe Magnet and Iron Filings

circuit by moving a magnet across the wires or by moving the wires across the "magnetic field," and this term must be now explained. Dr Gilbert observed the fact by sifting iron filings over a sheet of paper or glass and holding this over the poles of a magnet. By lightly tapping the filings are set in motion and the magnetic force arranges them in definite lines for a considerable distance, depending on the strength of the magnet.

The annexed cut (Fig. 76) shows the way the filings

arrange themselves over a bar magnet. Their greatest strength is seen to be at right angles to the two poles from which they radiate in all directions. In a horse-shoe magnet (Fig. 77) they also radiate from the two poles, forming arcs beyond them, while they form nearly parallel lines across the two arms of the magnet, where the force diminishes as they recede from the poles. In the next two cuts (Fig. 78 and Fig. 79) the contrasted effects of attraction and repulsion is shown, illustrating the law that opposite poles of a magnet attract each other while like poles repel.

The whole of the area through which these forces act is

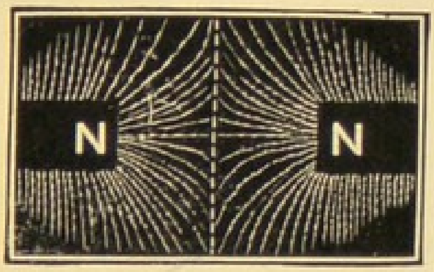


Fig. 78

Fig. 79

termed the "magnetic field," and the lines marked out by the iron filings, showing the direction and strength of the magnetic action, were termed by Faraday the "lines of force." He studied them carefully under varied conditions, and made great use of them in determining the laws of electro-magnetic action.

A simple mode of illustrating this phenomenon of induction is to have a coil of insulated copper wire with the ends attached to a delicate galvanometer (an indicator or measurer of electric currents) and a bar magnet. If this magnet is pushed quickly into the hollow of the coil a current is produced during the movement, but while it remains still there is no current. Again, while it is being rapidly pulled out there is another current, but in the opposite direction. The same thing happens if the coil is moved towards the

magnet as if the magnet moves towards the coil, and the more rapid the motion the stronger are these induced currents. An interesting point to notice is that the magnet which produces this effect is not weakened by thus acting, the real origin of the electrical force produced being the force expended in moving the magnet or the coil.

But besides the mutual induction of magnet and current Faraday also found that a current through one coil of wire will induce an instantaneous current in another quite detached coil of wire near it when moved quickly towards or away from it. The voltaic current acts as if it were a magnet.

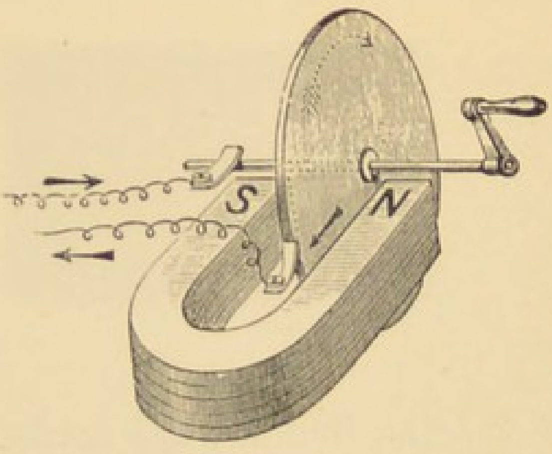


Fig. 80.—Faraday's Disc Machine

This principle of induction discovered by Faraday is the foundation of the modern dynamo-electric machines, commonly called "dynamos," used for generating the power for our electric trams and railways, and for the transmission of the power generated by water or wind to a distance. And similar dynamos are used for the production of the electric light or for the electric furnace. Faraday himself constructed simple machines of this kind, one of which is shown at Fig. 80. It consists of a copper disc rotated between the poles of a magnet. The current flowed from the shaft to the rim or the reverse, according to the way the disc was turned. In the modern dynamos the magnets are very powerful fixed electro-magnets, and the place of the disc is occupied by coils of copper wire wound on iron cores, and so arranged that some of them are always moving directly across the lines of force of the magnets

and so producing a continuous and uniform generation of current.

The modern dynamo will either convert mechanical force into electric currents or electric currents into force. Thus a waterfall may be used to drive a dynamo which produces powerful electric currents. These may be conveyed by conducting wires to a variety of places many miles distant,

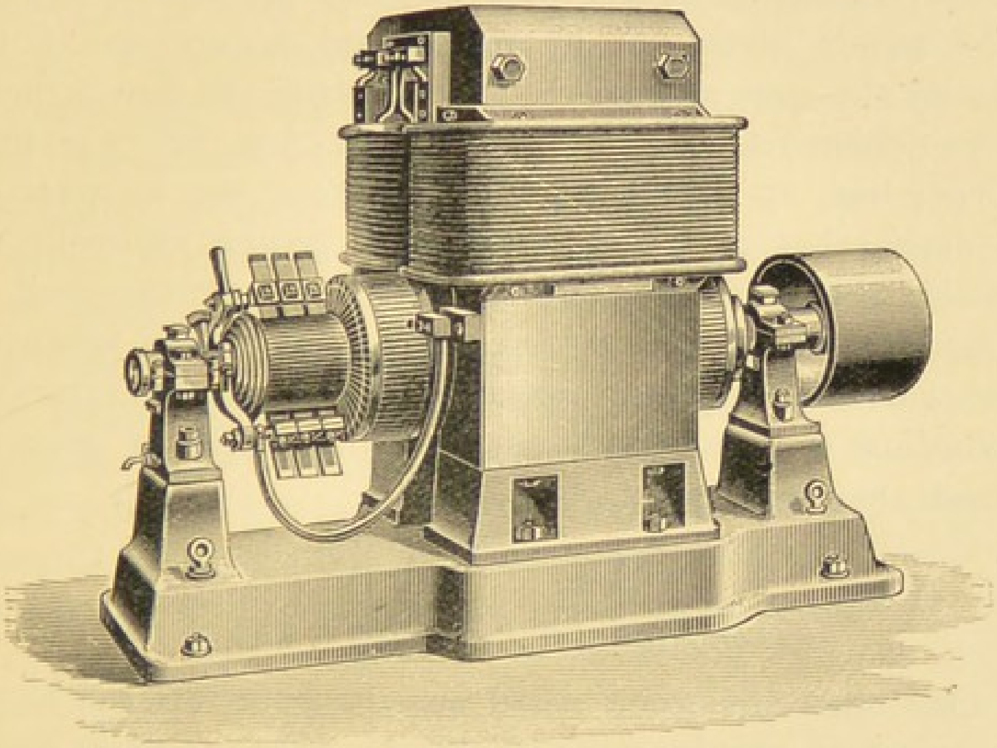


Fig. 81.—A Dynamo

and there, by means of other dynamos, in this case usually called "motors," be reconverted into mechanical force. The loss of power during this transmission is usually much less than when wire cables, or water or air under pressure, are used.

As the direction of the induced current changes according as the armature coils move across one or the other pole, an arrangement termed a commutator is attached, by which the currents in each coil are reversed each half revolution so as to give a continuous current in the same direction,

In some cases, however, alternating currents are used, in which case no commutators are required.

A dynamo is, therefore, a perfectly reversible machine. If the armature with its coils of wire is spun round by means of a steam-engine or water-wheel, electric currents are generated. And if these currents are sent through the armature of another dynamo (or motor) exactly like the first, it will revolve, and thus generate mechanical power. The power given out by the second dynamo would be exactly the same as that required to drive the first if there were neither friction nor loss of electricity in the connecting wires; but, as already stated, this loss is not so great as in most other modes of transmitting power, especially to considerable distances. But although the dynamo used as a motor *may* be identical with the dynamo which produces the current, they are usually different in construction, according to local conditions and the particular uses to which they are applied.

Transformers of Electromotive Forces

One other important detail may be here referred to, as its principle may be easily explained. Electromotive force of high voltage (which may be said to correspond to high pressure in steam or water power) can be transmitted to a distance with much less waste than the same amount of power at a low voltage. But the different purposes for which electric power is used require the current to be of very different voltages, and the change is made in each case by a transformer. This depends on the fact that when a secondary current is induced its voltage can be made higher or lower than that of the primary current, according as the coil of the secondary has more or less turns of wire than in the primary. A current can thus

be transformed up or down to any extent as desired, depending only on the strength of the insulating material to resist very high voltages.

Uses of Electricity

We may now briefly summarise the uses to which electricity in some of its forms has been applied in recent times. First we have the electric telegraph, which from its small beginnings in 1837 has rapidly covered the globe and the ocean-bed with its network of wires. The telephone, a quite distinct application of the electric current, supplements the telegraph for many purposes; and, more recently, wireless telegraphy comes in for purposes where the two former methods of communication are inapplicable. To the telegraph succeeded electric lighting in houses and streets, either by the brilliant electric arc or the more pleasant glow of the incandescent lamps. The marvellous X-rays are also produced by means of electricity, though their exact nature is still unknown. The electric spark is widely used in rock-blasting and in submarine operations. Electrotyping, or more generally electro-metallurgy, was one of the early applications of the electric current, and is now an important industry. In modern chemical analysis, electricity is very largely used, whether in the intense heat of the electric arc, which melts or volatilises the most intractable substances, or through decomposition produced by the voltaic current. And, lastly, we are now enabled to utilise a variety of natural forces by the facilities electricity affords us of transmitting those forces with very little loss to distant parts of our country.

This is, in truth, a marvellous series of useful applications of a natural agency which at the beginning of the

century was little more than a curiosity for the student and an amusement for the crowd, but which had been, so far, applied to no useful purpose whatever. And our present record is the more worthy of admiration, because it has not been a mere succession of applications of a simple force needing only a little mechanical ingenuity to ensure success, as has been the case in most of the mechanical advances of the century, but has had to deal with one of the most subtle and puzzling of all the phenomena of nature, which at almost every step has presented new and unexpected difficulties. These difficulties have only been surmounted through long-continued experiment by a band of earnest students, who at each step in advance have worked out the physical and mathematical laws of every movement or reaction, and who thus obtained a firm basis of knowledge from which to proceed to further developments. As a result of this careful study electricity is now a well-established science whose laws and modes of action are as well known as those of many of the less complex branches of physics.

But notwithstanding this large amount of knowledge of the phenomena and laws of electricity, its fundamental nature remains one of the greatest of mysteries. It is apparently co-extensive with the material universe, and it is excited by almost every change or motion that occurs in matter. Friction, percussion, or mere contact of unlike substances produces it. Changes of temperature, chemical changes, and physiological actions also produce it. It is present in the earth's magnetism; some of its grandest manifestations are the lightning and the aurora; and the vast and inconceivably rapid repulsive forces which produce the varied forms of the tails of comets are believed to be due to electric waves or repulsive forces excited by the sun's action.

When conveyed by conductors, the electric currents are limited to the surface of the wires, or they penetrate to a very small depth, while the internal part shows no sign of electricity. But a considerable portion of the current appears to flow quite outside the conducting wires, around which there is a magnetic or electrical field. This is found to retard the current on starting, but when the "field" is established there is no further loss. It has the opposite effect when a current is suddenly checked by breaking the circuit, and causes the spark then produced

Electricity may be said to exist under three different forms or manifestations: (1) as statical *charges*, which, when suddenly discharged, produce sparks or even lightning; (2) as currents, in which state it probably assists in the phenomena of the growth of living organisms; and (3) as whirls, which, passing around iron cores, produce electro-magnets, and in the earth, and perhaps in all suns and planets, cause the phenomena of magnetism.

It was proved by Clerk Maxwell that light is an electrical phenomenon, and his views are briefly stated by Professor Silvanus Thompson as follows:—

"In 1867 Clerk Maxwell put forward the theory that the waves of light are not mere mechanical motions of the ether, but that they are electrical undulations. These undulations are partly magnetic, oscillating electrical displacements being accompanied by oscillating magnetic fields at right angles to them, whilst the direction of propagation of the wave is at right angles to both. According to this theory the varied phenomena of electro-magnetism and of light are all due to certain modes of motion of the ether, electric currents and magnets being due to streams and whirls or other bodily movements in the substance of the ether, while light is due to vibrations to and fro in it."

The above statement is probably as precise and in-

telligible as any presentation of so difficult a subject can be made, and it serves to explain some of the remarkable contrasts in the two classes of phenomena. Light, for example, passes freely through glass, through air, and through a vacuum, while electric currents are stopped by all of them. This seems less puzzling when we look at light as mere vibration of the ether and electricity as actual movement of its substance. Yet it renders any clear conception of the essential nature of the ether more difficult than ever. But that is always the case as we approach the very origin and primary cause of any natural forces.

Professor Thompson considers Maxwell's theory—which is supported by other facts and mathematical reasoning which cannot be given here—to be "the greatest scientific discovery of the nineteenth century." His own views as to the nature of electricity are summarised as follows:—"Electricity is neither matter nor energy; yet it apparently can be associated or combined with matter; and energy can be spent in moving it. . . . It is apparently as indestructible as matter or as energy. It can neither be created nor destroyed. . . . In many ways its behaviour resembles that of an imcompressible liquid; in other ways that of a highly attenuated gas. It appears to exist distributed nearly uniformly throughout all space. Many persons (including the author) are disposed to consider it as identical with the luminiferous ether."*

This brief and most sketchy outline of what is known of the laws, the phenomena, and the applications of electricity, almost the whole of which are due to the workers of our own age, will, I think, be held to justify the title given to the present chapter, and will further, it is hoped,

* Silvanus P. Thompson's "Elementary Lessons in Electricity and Magnetism," 1895, pp. 1, 2.

impress the reader with the very exceptional nature of the laws and properties of this wonderful agency, and heighten his appreciation of the marvel and mystery of that inner and unseen universe of forces and causes upon which, in all probability, the visible universe of matter depends for its very existence.

CHAPTER XII

ASTRONOMY—THE SOLAR SYSTEM

" We may not hope to read
  Nor comprehend the whole
Or of the law of things
  Or of the law of soul:
Among the eternal stars
  Dim perturbations rise,
And all the searchers search
  Does not exhaust the skies."

F. P. PALGRAVE.

THE noble science of astronomy is the oldest of all the physical sciences. Historically, it can be traced back to 600 years before our era, when Thales, one of the seven wise men of Greece, observed and defined the solstices and the equinoxes, thus making four divisions of the year. Soon afterwards the cause of the moon's phases was explained, as well as why eclipses occurred; and the planets were distinguished from the fixed stars. But far earlier than these epochs we know that the heavens must have been carefully observed, because the position and structure of the Great Pyramid of Egypt could in no other way have been determined with such accuracy. Its four sides face to the four points of the compass, with such precision that when tested by means of the best modern instruments in the hands of a practised astronomer—the late Professor Piazzi Smyth—no error could be detected. In the same way it was found that the base was truly level and truly square; and, further, the gallery which slopes downwards from the north face to the deepest central chamber is at

such an angle as to point to the star which was nearest to the pole at the time the pyramid was built—about 3700 years B.C. The geometrical and astronomical knowledge indicated by this building, admitted to be the oldest in the world, must have been of slow growth, and therefore carries us back far into prehistoric times.

The Greeks continued to advance in astronomical knowledge down to the time of Ptolemy, A.D. 170; after which period the Arabs took it up, and made additional discoveries during the profound darkness of the Middle Ages in Europe. One of them, Albategnius, A.D. 900, determined the length of the year, a by no means easy measurement even now. He made it 365 days 5 hours 46 minutes 24 seconds, which is only two minutes too short; and, considering the absence of instruments or clocks, this is a marvellous performance.

Then, much later, comes the era of Tycho Brahe the observer, followed by that of Kepler the mathematician, whose determination of the elliptic orbits of the planets, and the relation of their distances and periodic times, stands out as one of the greatest works of the human intellect, and the foundation of scientific astronomy.

Immediately after this came the invention of the telescope in 1609 and the era of Galileo, Halley, and Newton. The rapid increase in the power of the telescope and the construction of more perfect measuring instruments, aided by the grand theory of universal gravitation, which not only gave the reason for Kepler's laws but furnished the means of explaining irregularities of motion which more accurate observation detected, prepared the way for that rapid advance of astronomy during the eighteenth century, culminating in the vast telescopic discoveries of Herschel and the wonderful mathematical investigations of Lagrange and Laplace. Miss Clerk, in her admirable "History of

Astronomy," well remarks: "The age succeeding Newton's had for its special task to demonstrate the universal validity and trace the complex results of the law of gravitation. The accomplishment of that task occupied just one hundred years. It was virtually brought to a close when Laplace explained to the French Academy, 19th November 1787, the cause of the moon's accelerated motion. As a mere machine, the solar system, so far as it was then known, was found to be complete and intelligible in all its parts."

With such wonderful progress both in the observation of the heavens and in the theory of the planetary motions, there hardly seemed much room for any great or startling discoveries except such as might arise from an increase in the size and power of telescopes; but the very reverse of this has been the fact. Modern telescopes have indeed enabled us to make many interesting and even some startling discoveries, but these constitute the very smallest part of astronomical progress during the nineteenth century. As in other sciences, so in this, there have been new departures in the field of research; new instruments with hitherto unimagined powers have given us new sources of knowledge in directions which were thought to be forever closed to human inquiry. And though the increased stores of knowledge we have gained by following the old lines are very great, it is through the agency of those quite new and most marvellous instruments of research—the spectroscope and the photographic plate—that we have conquered new realms in the heavens and have made considerable progress in the study of what has been termed the New Astronomy. We will now attempt to give some account of the more important of the discoveries which have been due both to the old and the new methods of research.

The Solar System in 1800 *and in* 1900

With the single exception of Uranus, discovered by Herschel in 1781, no addition had been made to the five planets known to the ancients till the commencement of the nineteenth century, when Ceres, the first of the minor planets, was discovered in 1801, and three others, Pallas, Juno, and Vesta, between that date and 1807. No more were found till one was added in 1845 and another in 1847. Since that time no year has passed without the detection of one or more new planets belonging to the same system, till at the end of the century their number amounted to over 450. This enormous increase is due to the fact that during the latter half of the century a number of astronomers devoted themselves to this special search, one alone having discovered no less than eighty-five, while several others have also added large numbers of these asteroids to our system. Since photography has been used as an engine of discovery these additions have been on a still larger scale, one observer having no less than ninety to his credit.

When these small planets were first discovered telescopic power was too limited or too rare in most observatories for anything to be learnt of the size or physical characteristics even of the brightest of them. But the large and powerful telescopes now in use have added somewhat to our knowledge. The brightest of all is Vesta, which has occasionally been seen by the naked eye; but it is not the largest. By observations with the great Lick telescope Professor Barnard has determined that Ceres is 485 miles in diameter, Pallas 304, while Vesta is only 243 and Juno 118 miles. The surface brilliancy, or "albedo," of Vesta is a very puzzling phenomenon, since it indicates an

atmosphere, as only clouds or snow can reflect so much light. An atmosphere, however, seems impossible in so small a body, as gravity would not be sufficient to retain the molecules of gases, and they would fly off into space. But as such a small body would cool very rapidly, it seems possible that if any considerable quantity of gases or vapours were contained in its interior when first formed, and these slowly escaped after the surface had cooled nearly to the absolute zero, they would, as they reached the surface, become liquefied or even solidified and remain in the form of gaseous snow. Such a small planet would perhaps rotate in a few hours, so that, if during the short day a portion of the solid gas were evaporated, before it could escape altogether it would be again frozen, and thus keep up the snowy covering.

Taken as a whole, these small planets occupy a belt about 240,000,000 miles wide, the centre of which is about one-third of the distance between Mars and Jupiter. The nearest to Mars is about 50,000,000 miles from that planet, while the most remote is more than 160,000,000 miles from Jupiter. Most of them travel in eccentric orbits, some having more than double the eccentricity of Mars, and their orbits are variously inclined to the ecliptic, Pallas having an inclination of 34°. Owing to these peculiarities their orbits continually cross those of others, and it has been said that if the path of each were represented by a solid ring, the whole mass would be found to be so entangled that they could be lifted up and carried away by taking hold of any one of them.

The asteroids are grouped somewhat more closely together at that distance from the sun where a planet should be placed to fill up the gap between Mars and Jupiter according to the rule termed Bode's law, which is as follows;—We take the series of numbers 0...3...6...12..,

24...48...96. Adding 4 to each gives us the proportional distance from the sun of the older planets, thus:

4	7	10	16	28	52	100
Mercury	Venus	Earth	Mars	—	Jupiter	Saturn

and the one gap between Mars and Jupiter is now filled up by the great belt of asteroids the densest portion of which is almost exactly at the required distance.

But besides this densest portion there is a region where the asteroids are much less abundant than the average—a kind of division in the great belt—and this is found to be situated where the period of revolution bears a simple relation to that of Jupiter, five revolutions of an asteroid at that distance being equal to two revolutions of Jupiter. The effect of this simple relation is that any asteroids at that particular distance would, after five revolutions be again in exactly the same positions with regard to Jupiter, so that the disturbance caused by the attractive power of the great planet would be cumulative and thus draw the small body farther away from the sun. But, having done so, the time of revolution would increase, and the simple relation between the two periods would cease to exist. The disturbance caused by Jupiter would then cease to be cumulative, and thus at a comparatively short distance on either side of the line there would be nothing to prevent the permanence of the orbits of any of these small planets.

Now this law, that, whenever the times of revolution of two planets are simply commensurable, cumulative disturbances occur which must result in one or both of them being forced into a larger or smaller orbit, seems to afford a clue to the actual distribution of the planets. For if we compare the periodic times of each of them with those nearest to it we find that in no case is there any approach to a simple relation between them. In fact, we cannot find a common measure of any two of them without going to

very high numbers involving hundreds or even thousands of revolutions. If, then, we suppose the planets to have been formed successively by aggregations of matter distributed throughout what is now the solar system, then the formation of new planets would be checked in any orbit where they would be subject to cumulative disturbance by their nearest neighbours. Hence all those regions would necessarily be void, and the successive planets would be found only in orbits of such dimensions that the periodic times resulting from them, according to Kepler's third law, were such as to avoid any cumulative disturbance by any other body in the system.

The Discovery of Neptune

The next great discovery worthy of notice is more especially interesting because it was at first only a prediction which was almost immediately verified by telescopic observation. It thus afforded a striking demonstration of the theory of gravitation, and a no less striking example of the powers of modern mathematics. It had been found that the motions of Uranus were not exactly what they ought to be if due solely to the attraction of the sun and the disturbing influence of Jupiter and Saturn, and it was thought possible that there might be another planet beyond it to cause these irregularities. In the year 1843 a young Cambridge student (John Couch Adams) of the highest mathematical ability, determined to see whether it was not possible to prove the existence of such a planet; and having taken his degree as Senior Wrangler, he at once devoted himself to the work, and after two years of study and calculation he was able to declare that a planet which would account for the perturbations of Uranus must, if it existed, be at that time in a certain part of the heavens, and he sent his paper on the subject to the Astronomer-Royal

in October 1845. By an extraordinary coincidence a French astronomer (Leverrier) had been for some years working out the motions of the various planets, and in doing so had also reached the conclusion that there must be another unknown body to produce the perturbations of Uranus, which were at that time unusually large. His calculations and results were published at Paris in November 1845 and June 1846, and he gave a position for the unknown planet differing only one degree from that given by Adams. On reading these papers, and seeing the agreement of two independent workers, the Astronomer-Royal asked Professor Challis, of the Cambridge Observatory, to search for the planet, and on doing so he actually observed it on 4th August and again on 12th August; but having no accurate chart of that part of the heavens he could not be sure that it was not a small star. A month later it was found and identified at Berlin from information furnished by Leverrier. It thus appears that Adams first privately announced the position of the new planet, and that it was first observed at Cambridge; while the somewhat later announcement by Leverrier and discovery at Berlin were made public, and thus gained the honours of priority. The two discoveries were, however, practically simultaneous and independent, and the names of Adams and Leverrier should forever be jointly associated with the planet Neptune.

The discovery of Neptune is not only a triumph of mathematical calculation, but it at the same time affords an illustration of the fact that the motions of the planets are determined by the law of gravitation alone, and that the smallest perceptible deviation from the course prescribed by that law can be at once detected by astronomical observation; and, in most cases, the cause of such deviations has been discovered by a more refined study of the effects of the same law. For many years astronomers had been

trying to reconcile certain deviations of Uranus from the course it should have pursued, if subject to perturbations by Jupiter and Saturn only, but without result, and at the time when Adams and Leverrier took up the problem the irregularities had become so large as to be considered a disgrace to astronomical science. Most persons will therefore imagine that the planet was found to be many degrees from its calculated place, or at the very least as far as the diameter of the moon. The fact, however, is that the greatest deviation from the calculated position was so small that if another planet or star of the same magnitude could have been placed in that position the two would to the naked eye have appeared to be one. The greatest amount of error in position was two minutes of arc, and when two stars are at this distance apart they appear as one to the best eyesight. Yet this small difference which had arisen after twenty years of accumulated deviation was sufficient to lead to the discovery of the unknown planet whose attraction fully explained it!

The Latest New Planet, Eros

One of the startling new discoveries of the century, and the most recent, is that of a new minor planet *not* belonging to the great belt of the asteroids, since its mean distance from the sun is less than that of Mars. It was discovered on a photographic plate at the Urania Observatory, Berlin, on 14th August 1898. Being immediately notified to other observatories, it was carefully followed for more than four months, when its orbit was calculated and was found to be a very extraordinary one. Its mean distance from the sun is 134,000,000 miles, that of Mars being 139,000,000, but its eccentricity is so great that more than two-fifths of its orbit is outside that of Mars, while more than half is so far within it as to

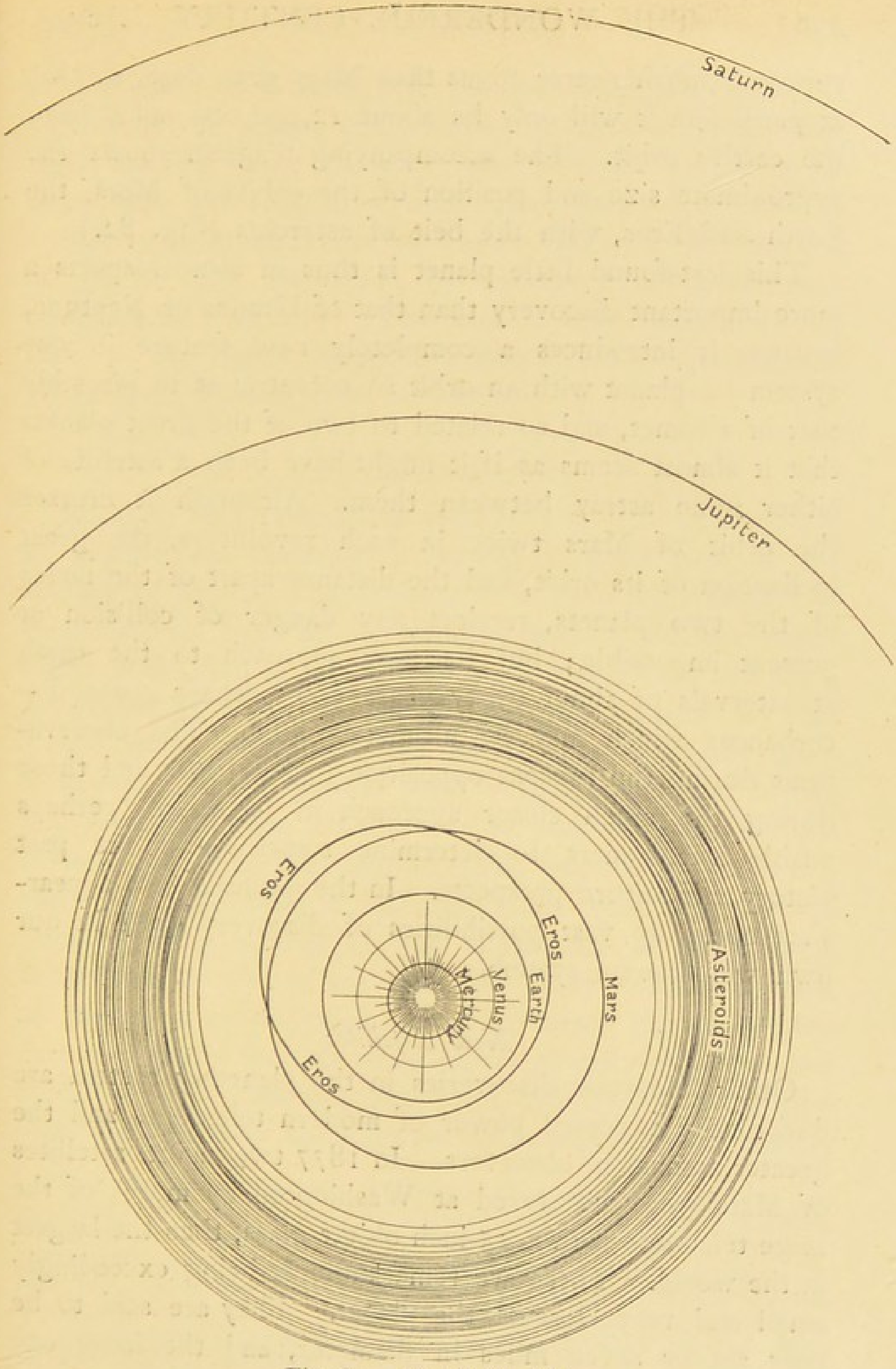


Fig. 82.—The Orbit of Eros

approach much nearer to us than Mars ever does, so that at perihelion it will only be about 12,000,000 miles from the earth's orbit. The accompanying diagram shows the approximate size and position of the orbits of Mars, the Earth and Eros, with the belt of asteroids (Fig. 82.)

This last-found little planet is thus in some respects a more important discovery than that of Uranus or Neptune, because it introduces a completely new feature in our system—a planet with an orbit so eccentric as to resemble that of a comet, and so related to two of the great planets that it almost seems as if it might have been a satellite of either gone astray between them. Although it crosses the orbit of Mars twice in each revolution, the great inclination of its orbit, and the distance apart of the nodes of the two planets, renders any danger of collision at present impossible; but its near approach to the earth at intervals of about thirty years will perhaps cause disturbances which may be ultimately fatal. The observations during the present opposition (1900-1901) and those during the much closer approach in 1924 will perhaps enable astronomers to determine something of its past history and future prospects. In the meantime, its appearance opens up vast possibilities of discovery even in our own well-known system.

New Satellites

Other important discoveries in the planetary system are due to the increased power of modern telescopes and the greater number of observers. In 1877 two minute satellites of Mars were discovered at Washington by means of the large telescope with a 25-inch object glass, then the largest in the world. These are remarkable in being exceedingly small and very close to the planet. They are said to be only six or seven miles in diameter, and the inner one

is only about 5800 miles from the centre, or 3800 from the surface of the planet, around which it revolves in less than eight hours; while the outer one is about 14,500 miles away, and revolves in a little more than thirty hours.[1]

Still more recently (in September 1892), a fifth satellite of Jupiter was discovered by means of the great Lick telescope in California. This also is very small and very close to the planet, being less than half the diameter, or about 40,000 miles from its surface.

The Canals of Mars

Another very remarkable discovery is that of a system of symmetrical markings, covering a large part of the surface of Mars. They consist of a series of triangles or quadrilaterals bounded by straight lines, which are sometimes seen double, at other times single, or are even altogether invisible. Another peculiar feature is that where these canals (as they are termed) intersect there is always a black circular spot, very distinct, and unlike any markings upon other parts of the surface. It is a curious fact that the double canals sometimes enclose a space of more than a hundred miles wide and several hundred long, adding to the appearance of artificiality. Sometimes no canals are seen, but they come into view as the polar snows begin to melt; hence the suggestion that they really indicate great canals to carry off the water from the rapidly-melting snow and distribute it by irrigation channels over the adjacent land, which, being rapidly

[1] In "Gulliver's Travels," published in 1726, Swift describes the astronomers of Laputa as having "discovered two lesser stars or satellites, which revolve around Mars; whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outermost five; the former revolves in a space of ten hours and the latter in twenty-one and a half." This is a wonderful anticipation, especially as to time of revolution, and if we substitute "radii" for "diameters," the distances are also very near.

covered with vegetation, causes the change of colour which renders them visible. These observations were made by Mr Percival Lowell during the favourable opposition, in 1894, at his observatory in Arizona, where the exceptional purity of the atmosphere renders it possible almost constantly to observe details which are elsewhere rarely visible.

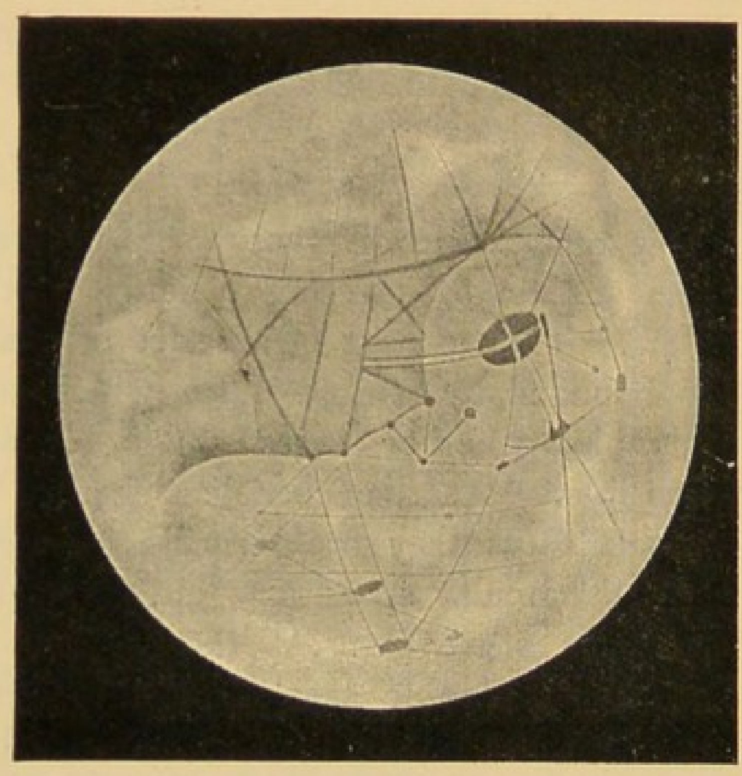


Fig. 83.—Mars, showing the Markings or "Canals"

But very similar results had been obtained seventeen years earlier during the very favourable opposition of 1877 by the director of the Milan Observatory, Signor G. V. Schiaparelli, an astronomer who had made other important discoveries in regard to Mercury and Venus. His chart of Mars has a striking general resemblance to the drawings of Mr Lowell, though having many differences, some of which are due to their being constructed on quite different methods. Schiaparelli's is a chart on Mercator's projection,

while Mr Lowell drew his on a model of the globe of Mars and then photographed the model. One of these photographs is reproduced in our Fig. 83.

Great doubt is still thrown on the very existence of the canals, or more properly "channels" as they were named by Schiaparelli, from their remarkable appearance. They are said to be optical delusion due to peculiar conditions; and the fact that the great telescopes at Washington and in California have not detected them is thought to be almost conclusive against their existence. On the other hand, the two astronomers who have seen them each gave up their time during a whole opposition to the study of the planet, the one in the clear atmosphere of North Italy, the other in perhaps the finest position in the world—on the mountains of Arizona. Optical illusions do not deceive experienced astronomers for months in succession, and although the interpretation of the canals as works of art is purely hypothetical and is almost certainly erroneous, we can hardly doubt that they represent some real features on the surface of the planet.

The True Nature of Saturn's Rings

The unique and wonderful ring which girdles the planet Saturn has, ever since its discovery, been a mystery for astronomers and a delight to all who could examine it through a good telescope. Galileo with his best but very imperfect instrument, magnifying thirty-two times, was surprised to see the planet widened out laterally as if two smaller planets were attached to it. He observed them for several months in 1610, and as they did not alter their position he was sure that they formed part of the planet, and he therefore declared that he had observed Saturn to be triple. But a year and a half later, when the planet again came into view, the appendages had disappeared and

the planet had as round a disc as Jupiter or Mars. He was puzzled and almost alarmed at this, saying: "Is it possible that some mocking demon has deluded me?" But a few years later they appeared again, and changed in form, seeming to send out arms towards the planet. He thus came very near to the discovery of their true character.

Larger and more powerful telescopes were made soon after, but though the appendages were seen like *ansæ*, or "handles," they remained a puzzle till Huygens, a Dutch mathematician and astronomer, after several years' observations, during which the "handles" disappeared and re-appeared more than once, by combining all the appearances and changes was able to announce, in 1659, that Saturn is girded about by a flat, thin ring, inclined to the ecliptic, and not touching the body of the planet. He also discovered the largest satellite, Titan. The curious disappearances and reappearances of the ring which so puzzled the first observers is due to the fact that, during the planet's revolution round the sun the plane of the ring being fixed in direction must at two points in its orbit pass through the sun, and the ring being very thin and truly plane no light falls upon it except on the edge which remains invisible. The edge is so narrow that it has only been detected by the best modern telescopes and under the most favourable conditions. The plane of the ring will also sometimes pass through the earth, when, of course, only the edge can possibly be seen. The dark stripe that divides the ring into two concentric portions was discovered by Ball in 1665 and confirmed by Cassini in 1675.

Nothing further was done till Herschel, in the latter part of the eighteenth century, studied the planet by means of his great telescopes, and proved that the dark stripe was a gap of exactly uniform width dividing the ring into two quite separate portions. He also thought that the outer

edge of the ring rotated in about ten and a half hours, now known to be too little.

During the nineteenth century many additions have been made to our knowledge of the rings. A very fine division has been detected in the outer ring, but it is only to be seen when the ring is most fully exposed, and in very good telescopes. At such favourable occasions many good observers have detected other dark concentric lines seen occasionally at the bend of the apparent ellipse where the rings appear widest, indicating that the rings are really made up of a considerable number of concentric rings, or are subject to changes in appearance indicating some amount of instability. But down to the middle of the century it had always been supposed that the rings were either solid or liquid and continuous. Laplace indeed had shown that in order to retain their form, if solid, the rings must rotate and must also be divided into at least three concentric rings, and the observed divisions supported his conclusions.

One other very curious discovery was made in 1850, that of an interior rather broad, dusky ring commonly called the crape ring. This has been seen by many good observers, and it is so transparent that the outline of the planet can be distinctly seen through it. This ring must have been seen by Herschel, but he mistook it for a dark belt across the planet, and there is some evidence that it has become broader since his time, as accurate measurements taken by the earlier observers are considerably less than those recently taken. There is also reason to believe that this dusky ring is thicker than the luminous rings, it having been seen faintly luminous on each side of the bright ring when that was seen edge-wise. (*See* Fig. 84.)

These various peculiarities of the rings, and especially the clear indications of several divisions in them, caused so many doubts as to their actual nature and possible stability

that the University of Cambridge, in 1855, gave this as the subject of the Adams Prize Essay, and in 1857 the prize was awarded to Mr J. Clerk Maxwell. By a profound mathematical investigation he proved that either solid or liquid rings would be unstable, and would inevitably break up so as to form a number of satellites; and he concluded that the rings really consisted of a crowd of small bodies so near together as to appear like a solid mass; and as the appearance of the rings, and some slight changes detected

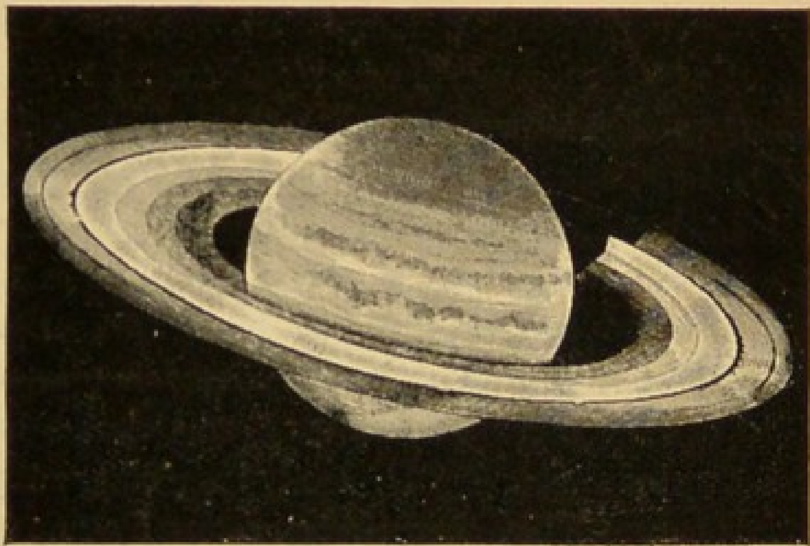


Fig. 84.—Saturn

in them, were in harmony with this view, it has been generally accepted. But quite recently the wonderful instrument the spectroscope has given the final demonstration that this theory is correct. If the rings are solid, it is clear that a point on the outer edge must move more rapidly than one on the inner edge; whereas, if they consist of separate particles, each revolving independently round the planet, then, in accordance with the laws of all planetary motions, those forming the inner side of the rings, being nearer to the planet, must move much quicker than those on the outer side. As will be explained in

Chapter XIV., the spectroscope enables us to measure motion in the line of sight—that is, towards or away from us—of any heavenly bodies, and by observing the outer extremities of the rings to the right and left of the planet, where the motion is, of course, in these two directions, it is found that the motion of the inner edge is considerably more rapid than that of the outer edge, showing that those parts move round the planet independently, and are therefore formed of separate particles or small masses. These observations were made by the American astronomer, Professor James E. Keeler, in 1895, and are of extreme delicacy; but that they are trustworthy is shown by the fact that the resulting velocities are in accordance with Kepler's third law, which determines the relative motions of all planets or satellites at different distances from their primaries.

It seems strange that minute bodies like those forming Saturn's rings, each revolving around the planet like a separate satellite, can be close enough together to appear to us as solid as the planet itself. But it must be remembered that we see them at the best very obliquely, and that the thickness of the rings, though very small, is at least fifty and perhaps a hundred miles. If, therefore, these meteorites are, as supposed by Clerk Maxwell, only a few inches to a few feet in diameter, they might be on the average several hundred feet apart, and yet appear to us as a continuous surface. Moving, as they must move, under the influence of the law of gravitation no one of them could deviate from its proper orbit so as to overtake another, except when disturbed by the nearest satellites, but as these move almost exactly in the plane of the rings, and in nearly circular orbits, the disturbances would not be great. It is considered, however, that such disturbances must occur, and must result in the ultimate destruction

of the rings, some falling into the planet as meteorites fall upon our earth, others spreading outward and by slow aggregation forming, perhaps, another satellite. But the first indication of an outward spreading should be the formation of an exterior "crape ring" of which no trace has yet been detected. The numerous dark lines occasionally seen in the rings may, Mr Proctor thinks, be explained by temporary disturbances due to the combined attractions of the nearer satellites.

While, therefore, it is held that the rings indicate a comparatively early stage in a planet's development and cannot be permanent, yet they appear to have attained a condition of general stability, and their disappearance will be only effected through slow changes continuing probably for many millions of years.

Comets, Meteors, and Meteoric Rings

Comets have been looked upon in all ages as marvels and portents, due not only to their strange forms and their enormous tails sweeping across the sky, but also to the abruptness of their appearance and their rapid changes of position. Newton observed a comet in 1680 which passed very close to the sun, and he showed that it obeyed the law of gravitation, but as it did not return, and has not been shown to be identical with any earlier comet, it was probably one of those which, being drawn out of the depths of space by the sun's attraction, pass round him in an open or hyperbolic orbit, and never return.

The one great and important discovery relating to comets before the nineteenth century was that made by Halley (afterwards Astronomer-Royal) in 1682. A large comet appeared in that year, and he calculated the elements of its orbit on Newton's principles, and found them to

agree so closely with elements, similarly calculated, for comets which had been observed in 1531 and 1607, that he felt sure they must be returns of the same body, which would thus have a period of revolution round the sun of seventy-six years. He accordingly predicted its return in the winter of 1758-9, and he appealed to a "candid posterity" to acknowledge that this great discovery was made by an Englishman. Halley died in 1742, and on Christmas-day 1758 the comet duly appeared, and again in 1835, when it passed within 4½ million miles of the earth, and presented some extraordinary appearances. At first its nucleus was very brilliant, with emanations towards the sun.

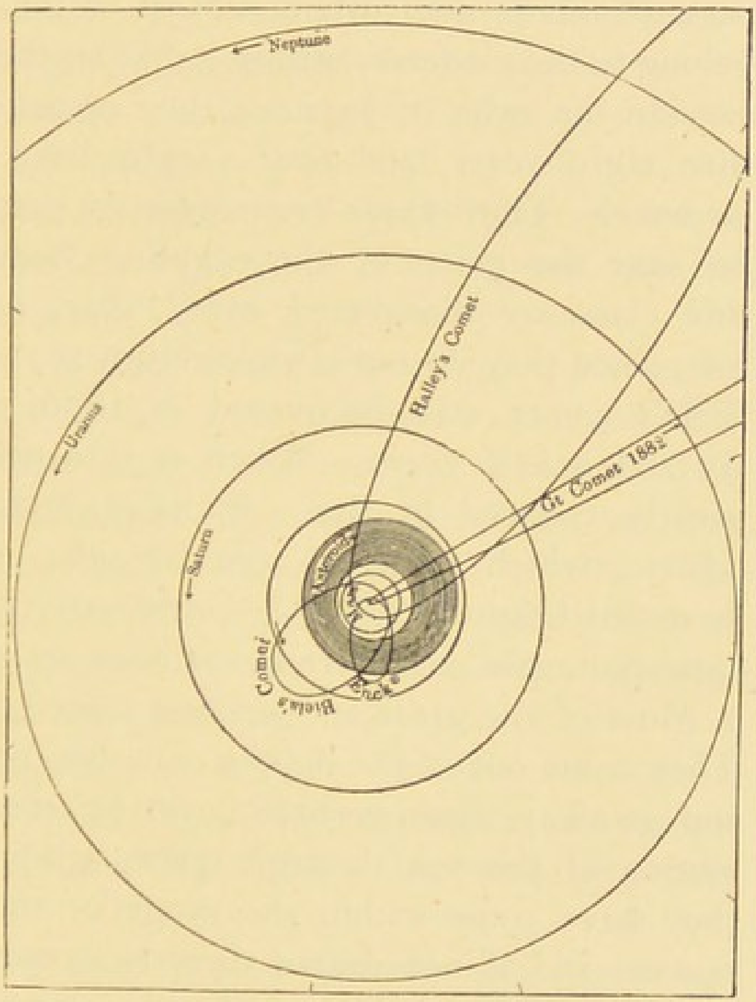


Fig. 85.—Orbit of Halley's Comet

In a few days these seemed to be swept backwards, and soon produced an enormous tail 24° long. After passing around the sun it reappeared as a nebulous star, and soon vanished. This is known as Halley's comet (*see* Fig. 85), and its return is expected in 1910. Its orbit extends to two and a half times the distance of Neptune. With

this one exception all we now know about comets is a product of research during the nineteenth century.

More than twenty comets are now certainly known to belong to the solar system, and many others have apparently elliptical orbits, and are therefore probably periodic, but as they have only been observed during one perihelion passage this is not certain. Most of the periodical comets belong to the planetary group—that is, they do not circulate outside the orbit of Jupiter; they return in periods of less than eight years, and they usually have but a small tail, or none. They move from west to east like planets, and lie near the plane of the ecliptic. Some new comets of this class are discovered every year, but some also are lost, since they do not always return at their proper epochs. Biela's comet was discovered in 1826, with a period of six and a half years. When it returned in 1832 it was greatly reduced in size. In 1845 it had split into two comets, which travelled side by side, and both were of increased brightness, and had moderate tails. In 1852 they appeared again, and have never been seen since.

Most of the great and striking comets are seen but once. They come out of the depths of space, pass round the sun, and go away, again perhaps never to return. Either by the motion of the sun through space, or by their own motion, they have come within the range of the sun's gravitating power, and if not drawn directly towards it they assume a parabolic curve which carries them again into space. But if during their outward journey they should come within the attractive influence of the greater planets their course may be changed to an ellipse, and they then become members of the solar system. Such was probably the case with Halley's comet, which is supposed to have been captured by Neptune. About twenty-five comets are believed to have been thus drawn into our system by

Jupiter, and these include most of the planetary comets; nine are imputed to Saturn, eight to Uranus, and five to Neptune. Many of these have paid us only one visit, but they have been observed during several months. so that their orbits could be shown to be elliptical and their periods very long.

The great comet of 1811 was the first of importance in the nineteenth century. It moved slowly on account of its orbit being wholly outside that of the earth, and remained visible for nearly a year and a half. It was carefully observed and described by Sir William Herschel. It appeared as a hollow cone of a bluish green tint enveloped in a transparent veil of a yellowish colour. The planetary disc of the head was 127,000 miles across, of condensed nebulous matter with a star-like nucleus of a reddish tinge. When nearest the earth, in October 1811, its broad and magnificent tail covered $23\frac{1}{2}^{\circ}$ of the heavens, and was about 100,000,000 miles in actual length. The bright envelope separated from the head by a dark interval and extending away from the sun to form the tail, suggested to Olbers the theory of electrical repulsion, first from the head of the comet, but with far greater force from the sun, as best explaining the remarkable phenomena of these objects, a view that is now becoming generally accepted.

Halley's comet in 1835 presented somewhat similar appearances and well illustrates the extraordinary and rapid changes these objects often undergo. When first dis covered at Rome it had the appearance of a nearly circular nebula. A month later it began to throw out a tail, which in another month reached a length of 24°, or even 30°, as seen in India. Bessel described an outrush of luminous matter of a fan-shape *towards* the sun, and then at a short distance, like smoke driven by a high wind, it was violently

swept backward in a prolonged train. He further noticed that the fan of light moved slowly backwards and forwards across a line joining the comet's nucleus and the sun in a period of about four and a half days, and he concluded that a powerful repulsive force, about twice that of gravity, was required to produce these effects.

Perhaps the most extraordinary comet of the century was that which was first seen both in America and Europe, close to the sun, on 28th February 1843. It appeared as a bright dagger-like object closely following the sun towards the western horizon. In Italy it was seen at noonday by shading the eyes from the sun itself, from which, however, it was less distant than the sun's diameter. The tail rapidly developed, and early in March was 25° long, while a little later, in Calcutta, another tail was seen making an angle of 18° with the first.

In England it was first seen on the 17th of March, when a silvery ray, 40° long and slightly curved at the end, shone out at sunset. It was narrow and well-defined, and of the enormous length of 200,000,000 of miles. The comet had just passed perihelion when first seen, and its centre could have been only 100,000 miles from the sun's surface, which it passed at the rate of 366 miles in a second. It must, therefore, have passed through the denser part of the sun's corona, from which, however, it escaped apparently uninjured.

After an interval of thirty-seven years another comet appeared in the southern hemisphere similar in many respects to that just described. It travelled in almost exactly the same course, from north to south, far away from the ecliptic, and had an enormously long tail. This was altogether fainter than its predecessor, and rapidly faded away. But two and a half years later, in 1882, yet another comet suddenly appeared, first seen at Rio Janeiro and

other southern observatories on 3rd September, and by Dr Common at Ealing on the morning of 17th September, close to the sun. A few measurements were taken when the sky became cloudy, but at the Cape of Good Hope it was seen continuously quite up to the sun's limb when it suddenly vanished, passing across the sun's disc. The next morning it was seen just before sunrise, extremely brilliant; and all over the world wherever the sky was clear it was visible during that day (18th September) by merely shading the sun from the eye. Since 1843 nothing had been seen like it. In the south of Europe it was seen for three days, and often at noon. It was, therefore, of excessive brilliancy. It was observed by numerous astronomers both before and after its perihelion passage, and was not finally lost till June 1883, when it was 480,000,000 miles from the earth. Its tail was about equal in length to that of the comet of 1843, being 200,000,000 miles long and of considerable breadth, and it was well seen in this country before sunrise on the mornings of October 1882.

The long-continued visibility of this comet enabled its orbit to be computed with great accuracy. This was found to be a very eccentric ellipse, and its period at least 770 years, and perhaps much longer. It was, therefore, clearly not a return of the two preceding comets here referred to; but the paths of these, and of at least two or three others less conspicuous, seemed to be identical, indicating that a number of comets may follow each other in the same orbit, thus forming what have been termed "cometary systems." This last comet furnished evidence of how such systems may originate by disruption. Its nucleus was observed to have two centres on 5th October, and later on a division into *three* was observed; a few days later there were *four*; while in January 1883 Dr Common saw *five* nuclei in a line along the centre of the tail. Other

nebulous masses were observed (at Athens and in the United States) a little behind the comet but travelling in the same direction, and it seemed as if these were some of its debris separated from it by the commotion excited in it during its close passage round the sun, when the comet was only 300,000 miles from its surface. It must have passed through the outer part of the corona, yet the comet's path was not disturbed, since it followed the same curve before and after its passage.*

Of all the comets of the century, Donati's, which appeared in the autumn of 1858, was the most beautiful and the most generally seen in this country. It was visible in the evening skies, and the weather was generally fine during the period of its greatest brilliancy. Its nucleus was as bright as Arcturus, its tail was bright and beautifully curved, with lateral radiating offshoots, which gave it the appearance of a delicate plume, while a long, straight ray diverged upward from near the base. (*See* Fig. 86.) The convex side of the tail was very bright, and it covered, at its maximum, a space of 40° of the heavens, and an actual length of 50,000,000 miles. I myself saw this comet in the Moluccas from 9th October to the 13th, just at the time when it was nearest the earth and at its greatest brilliancy. It was seen for some hours after sunset, and closely agreed with the descriptions of it as seen in Europe and America. Donati's comet was visible to the naked eye for more than three months, and telescopically for nine months. Its orbit is a very elongated ellipse directed far away from the courses of the planets. At perihelion it was nearer to the sun than Venus, while its orbit will probably extend to five and a half times as far as the orbit of Neptune, and it is not expected to return for 2000 years.

* Most of the facts with regard to these and other comets are derived from Miss A. M. Clerk's "History of Astronomy."

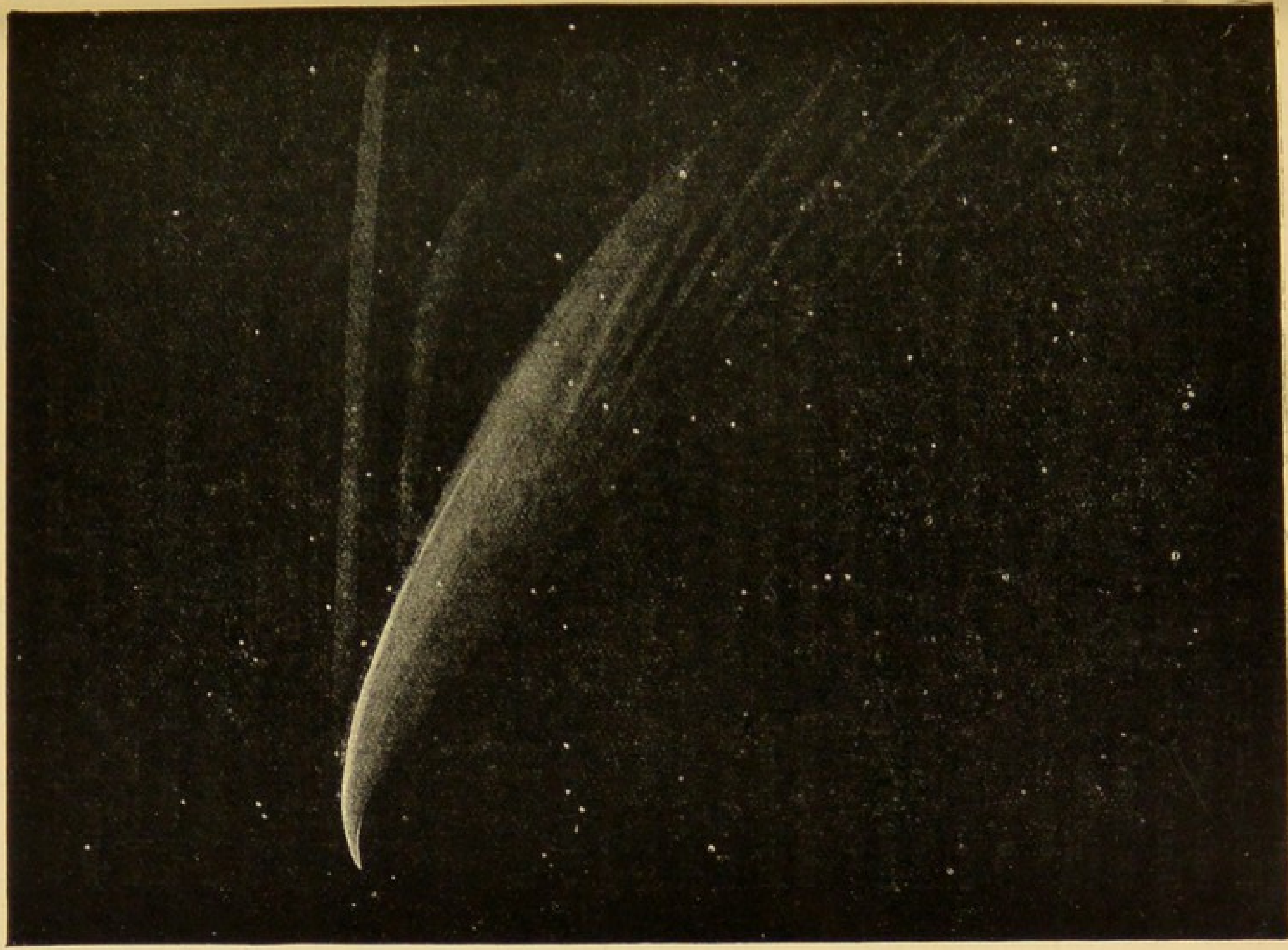


Fig. 86.—Donati's Comet, 9th October 1885
(From Langley's "New Astronomy"

Twice during the nineteenth century—in 1819 and in 1861—the earth has passed through a comet's tail, but in both cases without any special effects being produced. These and many other facts prove that the tails of comets are formed of such highly rarified matter—many million times less dense than our atmosphere—that it is only their enormous bulk that renders them visible, just as the comparatively minute patches of vapour in the clouds are so distinctly visible and appear almost solid. The heads of comets give out some light of their own, and also reflect the sun's light.

Comets, whether large or small, contain an extremely small amount of matter, so that their gravitative power is infinitesimal. A comet has been known to pass among the satellites of Jupiter without in the least degree affecting the regular motions of those bodies. But the bulk of some is enormous. That of 1811 had a nebulous head more than twice as large as the sun, while the tail was perhaps a thousand times larger. An astronomer once said that probably a comet could be put into a sack and carried on a man's back, and this was not altogether a joke, since it might be literally true of some of the smaller comets.

Comets are now believed to be really meteor swarms—but probably consisting of minute particles—a kind of huge dust-clouds, partly formed of various gaseous carbon compounds. As they approach the sun great tidal disturbance occurs, and intense electrical excitement is produced, to which much of the light of the nucleus is due. As it still nears the sun the electrical forces increase and cause violent repulsion, which drives off the minutest particles of matter producing the tails. It must be remembered that while these tails are being formed the comet, near its perihelion, is moving with great velocity, and every separate dust grain thus driven away retains its onward motion and

thus for a long distance forms an apparently straight line pointing away from the sun, just as a heavy ball thrown up vertically from the deck of a steamship moving twenty miles an hour will fall back into the thrower's hand.

The fact that electrical repulsive forces are so much more powerful than gravity is due to the difference of their laws, gravity being in proportion to the mass, while electrical force is proportional to the surface. Hence the smaller the size of the particles the greater becomes the superiority of electrical repulsion over gravitation. The electrical forces also depend partly on the nature of the matter affected, and the result is a considerable diversity in the actual as well as the proportional force of repulsion. It follows, that, when the electrical repulsion is very great, the tail will consist of particles driven off with enormous velocity in a straight line as shown in the photograph of Swift's comet, which enables us almost to see the tremendous outrush of the tail (Fig. 87), but when the repulsive force is less energetic, gravity acts so as slightly to draw back some of the matter, producing the curved form, as illustrated in Donati's comet (Fig. 86).

The spectroscope indicates the various sources of the light of comets. The spectrum of the hydro-carbon gases is generally seen; with it there is usually a continuous spectrum due to the ignition of minute solid particles, and there are also indications of reflected sunlight. The chief peculiarities of the spectra of comets have been reproduced by powerful electric discharges through tubes filled with carbonic-oxide and olefiant gases; while Sir Norman Lockyer has shown that a mixture of the material of meteoric stones in a vacuum tube, when subjected to the intense heat of electric sparks, gives a spectrum almost identical with that of the heads of comets. Those which

do not make a near approach to the sun are often without carbon bands in their spectra.

The tails of comets consisting of actual matter driven off from the head, it is evident that from this cause alone comets must diminish in bulk and ultimately disappear, and this will occur more quickly in those that more nearly approach the sun, where tidal and electrical forces lead to actual disruption. It has long been held by astronomers that all comets which belong to the solar system are in a state of decay and disintegration, due mainly to the unequal attraction of their parts by the sun and planets, and the various interesting phenomena here summarised have converted this opinion into a well-established fact.

Some further light is thrown on the nature and origin of comets by their connection with meteor streams, which will now be briefly described.

Meteors and Meteor Streams

Not least among the important discoveries which are wholly due to the nineteenth century is that relating to the above-named objects which before were almost wholly neglected. A careful study of these apparently erratic appearances has shown that they follow certain laws, and that it is possible to explain by one consistent theory the various phenomena presented by aërolites, fireballs, and shooting or falling stars, now generally classed as meteors and meteorites; and this theory is found to have an important bearing on the constitution of the solar system, and perhaps even on that of the whole stellar universe.

Although there are records of the fall of solid stones from the sky in the works of classical, Chinese, and European authors, from 654 B.C. down to our times, while the astronomer Gassendi, in the year 1627, himself witnessed

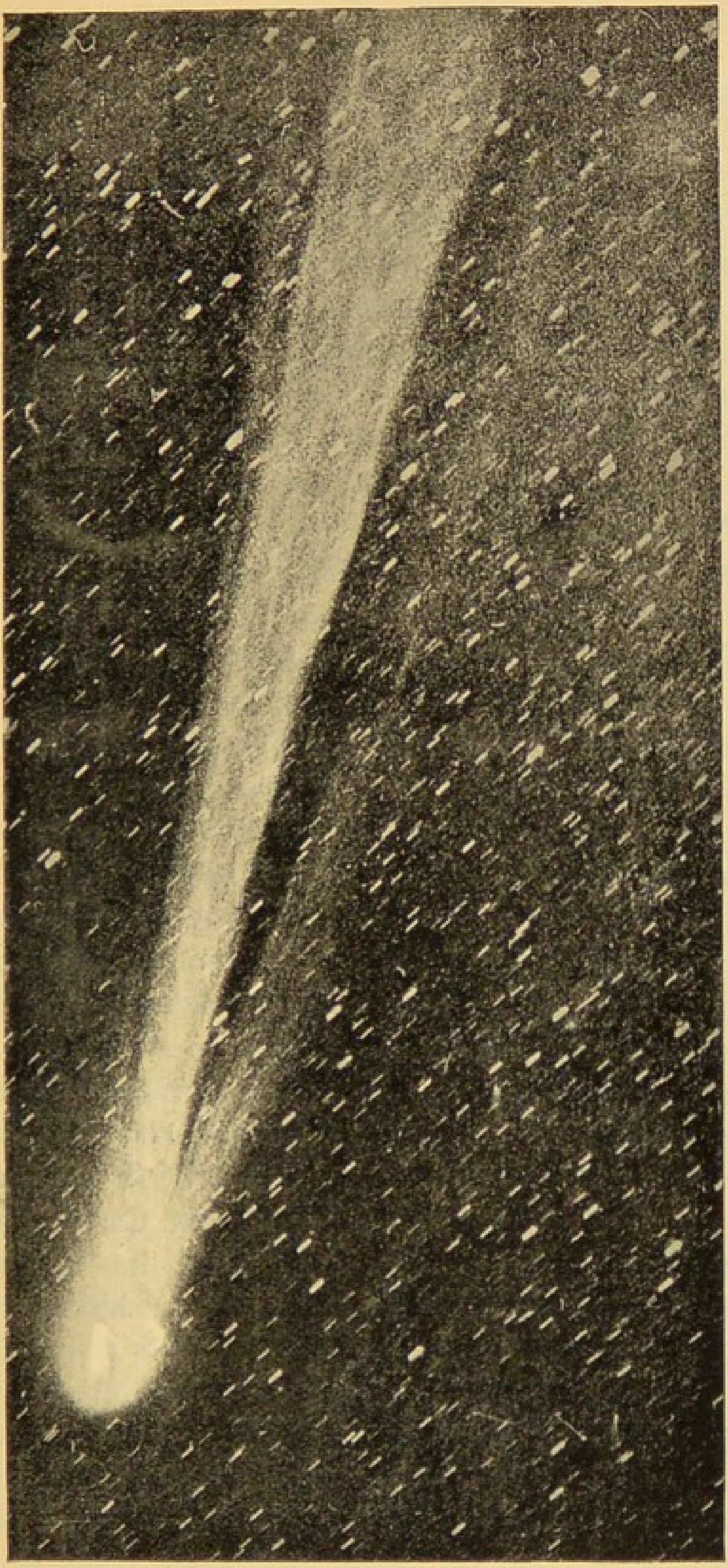


Fig. 87.—Swift's Comet

the fall of a stone weighing 59 lbs. in the south of France, yet the phenomenon was so rare, and so inexplicable, that it was often disbelieved. One philosopher is reported to have disposed of the whole matter by saying, "there are no stones in the sky, therefore none can fall from it." But the evidence for such falls soon became overwhelming, and their connection with fireballs and shooting stars was also well established. One of the most remarkable of modern meteors was that seen at Aigle in Normandy, on 26th April 1803. About 1 P.M. a brilliant fireball was seen traversing the air at great speed. A violent explosion followed, apparently proceeding from a small lofty cloud. This was no doubt the product of the explosion which would become visible long before the sound was heard; and then came a perfect shower of stones, nearly three thousand being picked up, the largest weighing eight pounds. A still more extraordinary meteor was seen on 19th March 1719, about eight o'clock in the evening, in all parts of England, Scotland, and Ireland. In London it appeared like a ball of fire as large as the moon; at Exeter the light was like that of the sun. It was followed by a broad stream of light, and burst with a report like that of a cannon, with a great display of red sparks like a huge sky-rocket; but as it was then over the sea, between Devonshire and the coast of Brittany, its fragments were not recoverable. Dr Whiston, Newton's successor as professor of mathematics at Cambridge, who published an account of it, calculated its height over London as fifty-one miles, and over Devonshire thirty-nine miles.

Falling stars, sometimes seen singly, at other times in considerable numbers, as well as the less frequent but larger fireballs above described, appeared to be connected phenomena, although little was really known about them

till the early part of this century, when they began to be more carefully studied. By observations of the same meteor or fire-ball at distant localities, its altitude, and the velocity with which it moved, were ascertained, and these were always found to be so great as to show that these objects could not have a terrestrial origin. It was soon observed that showers of falling stars occurred about the same time every year, with displays of great brilliancy at long intervals; and on these occasions the meteors all appeared to radiate from certain definite points in the sky. Thus in November they seemed to originate in the constellation Leo, and in August in Perseus, while others apparently belong to distinct constellations. The only way of explaining these appearances seemed to be that there were streams of small bodies travelling in elliptic orbits round the sun, and that the earth crossed these orbits at fixed points once a year. Then, a number of these small bodies, many of them perhaps no larger than pebbles or grains of sand, coming into our atmosphere, became heated and even vaporised by the friction due to their rapid planetary motion, and appeared to us as shooting stars; while larger masses, whose exterior alone became heated, either exploded or fell entire as meteorites. The exceptional displays of the November meteors at intervals of about thirty-three years is due to the fact that the stream is much denser in this part of its orbit, where the meteoric matter may be slowly aggregating to form a planetary body.

The explanation of the "radiant points" from which the various groups of meteors seem to arise is as follows:—At each hour during our journey round the sun the earth's motion is directed to one particular point in the heavens, and as it is our motion that brings us into contact with the meteor streams, they, of course, appear to arise at that par-

ticular point towards which we are moving. The August meteors, for instance, all radiate from a point in the constellation Perseus, because we are then moving directly towards that point. The earth's rotation on its axis makes no difference in the position of the radiant point, clearly proving that the meteors do not in any way belong to the earth but come to it from without. But the radiant point will be somewhat changed by the direction and speed of the meteor ring itself, and this is found to be the case. When the meteor ring is so wide that we take several days going through it our own direction will change somewhat; and if the meteor ring should be travelling much faster than we are, and in a very different direction, then the direction in which the meteors appear to fall will be altered, though the radiant point will remain the same.

Meteors are to be seen every clear night in the year, and by carefully observing these for a succession of years, about 3000 radiant points have been determined, each due to a separate meteor ring which happens to traverse our orbit sufficiently near to be drawn into our atmosphere. It has been calculated by Professor Newton of Yale College that seven and a half millions of meteors enter the earth's atmosphere every day; and, if we add to these the much greater number that must escape observation, it is supposed that the actual number may be several hundred millions. Of course it is only by a kind of accident that the orbit of our earth crosses any of these meteoric streams, so that there are certainly a vast number, perhaps even millions, of such streams in the solar system, since some thousands are either known or suspected to cross our path. Taking into consideration these numerous meteor streams moving in elliptic orbits round the sun, together with the vast number of stray meteors, as it were, indicated by those that are seen every day in the year, and by the exceptionally large

and rare fire-balls, we are led to the conclusion that the space occupied by the solar system, instead of being almost empty, as formerly supposed, is really strewn with solid bodies varying in size from that of dust or sand-grains up to huge masses a thousand times that of our earth.

The Relations of Comets with Meteor Rings

We now come to the most interesting discovery in relation to these two erratic phenomena — comets and meteors—the proof that they are closely connected and that comets are really parts of meteor rings, or, perhaps more correctly, that meteor rings are due to the disintegration of comets.

The orbit of a meteor ring was first calculated by Olmsted of Yale College in 1834, and thenceforth many other orbits were determined by astronomers as successive displays of meteors furnished the materials. It was also proved that the constituents of these rings travelled with velocities greater than that of the earth, and that their tracks usually resemble those of comets in being very eccentric and in lying at all angles to the ecliptic. Then came the great discovery. Professor Schiaparelli of Milan announced, in 1862, that the August meteors, known as the Perseids, move in exactly the same orbit as the comet of 1862, which was visible in this country in the evenings of the end of August, and had a rather faint tail about 20° in length. Soon afterwards the orbit of the November meteors —the Leonids—was identified as that of the Tempel's comet of 1866, having a period of about thirty-three years. These meteors produced the magnificent display in the northern hemisphere in 1833, and the still finer one, as regards this country, in 1866, which all who saw it declare was never to be forgotten. These had also been seen by

Humboldt in South America in 1799, and by the help of this and still earlier records Leverrier showed that this comet first came into our system in the year 126 A.D., when it must have passed near Uranus, and was by it diverted from a hyperbolic to an elliptic path. Since then, by the causes already stated, much of the matter of the comet has become diffused into the ring of meteors, the last grand display of which has probably been seen. In 1899-1900 when it should have been repeated, very few appeared, and it is believed that the denser portion has become so much diffused by planetary retardation that no future display will occur.

In the case of Biela's comet, which had a period of six and a half years, a diminution of size was observed from its discovery in 1826 till 1845, in which year it appeared split into two, and considerably brighter. Once again the two appeared, in 1852, but they have never been seen since. But a meteor ring—the Andromedes—having the same orbit and producing a display of meteors every thirteen years, at the end of November, has increased in size, the meteors becoming more numerous owing to their having been reinforced by the debris of the comet. In 1872-1885 and in 1892, very brilliant displays of these meteors were observed in America. They had been known since 1830, but their increase in numbers since the comet disappeared seems to show that we have here an actual example of how meteor rings have been produced or increased by the disintegration of comets.

Many new comets are seen every year, and are often not seen again. That these are fresh immigrants from the stellar spaces is indicated by the fact that nearly twice as many enter our system on the side towards which the sun is moving than on the opposite side.*

* "The Meteoretic Hypothesis," p. 249. By Sir N. Lockyer.

Summary of Discoveries in the Solar System

In reviewing the discoveries within the solar system during the nineteenth century we find that they present the same general features as the discoveries in other sciences here recorded, of being essentially new departures distinct from any of the advances that had been made in any preceding century, and that they have given us more accurate and more extended views of the constitution of the universe. Of course, the actual limits of a century are, as regards human progress, a purely artificial division of time, and if we claimed Sir William Herschel's discoveries at the end of the eighteenth century as coming within our limits, the contrasts between the two periods would be yet more striking. No planet had been added to those known to the ancients when Herschel discovered Uranus. Since then Neptune has been predicted and found, an intellectual triumph altogether without precedent; about 450 small planets forming the great belt of asteroids have been made known; the new planet Eros, absolutely unique in the solar system, inasmuch as its eccentric orbit lies partly within and partly without the orbit of one of the major planets, and therefore, though small, of intense interest; the two satellites of Mars, and the minute satellite of Jupiter, both unexpected discoveries; the demonstration that Saturn's rings are formed of minute satellites; the determination of the real nature of meteorites and of meteor showers; and, finally, the demonstration that comets and meteor-rings are portions of one phenomenon; that the former have come to us out of the depths of space and have been often retained in our system by the attractive force of some of the planets; the explanation of the mystery of comets' tails, and the proof that comets and meteor streams circulate throughout the solar system in countless thousands, and

that the former necessarily disintegrate and are transformed into the latter, constitute a series of discoveries which no previous century can approach, and which have given us a totally new conception of our own system, while at the same time they have furnished data of the highest importance for a comprehension of the stellar universe itself. Let us briefly consider this latter point.

The Old and the New Solar System

The eight major planets are so remote from each other that if we represent the solar system as an open plain two and a half miles in diameter, our earth will in due proportion be shown by a pea, Venus by a smaller pea, Mars by a large pin's head, Jupiter by an orange, Saturn by a small orange, and Neptune, on the extreme outer edge, by a largish plum. From any one of them the nearest would be invisible to us unless brilliantly illuminated, and however smooth and open was the plain, we might walk across it again and again, and with the exception of the two-foot ball in the centre representing the sun, we should probably declare it to be absolutely unoccupied. Looking thus at the solar system, the vast emptiness, the absurd disproportion of the sizes of the planets to the immense spaces around and between them, was almost oppressive; and even when we took account of the nebular hypothesis, and tried to imagine a mass of elemental gaseous matter occupying a sphere of the diameter of the orbit of Neptune, gradually cooling and shrinking, leaving rings of diffused matter behind it, which afterwards broke up and aggregated into the planets and satellites already known to us, the hypothetical solution of the problem was hardly satisfying, since it seemed difficult to understand how so vast a *plenum* could be converted into an equally vast *vacuum*, except for the

few and remotely-scattered planetary systems as its sole relics.

But the study of the long-despised and misunderstood meteorites and falling stars has entirely changed our conceptions of that portion of the universe of which our sun is the centre. We are now led to regard it as more nearly approaching a plenum than a vacuum. We know that it is everywhere full of what may be termed planetary and meteoric life—full of solid moving bodies forming systems of various sizes and complexities, from the vast mass of Jupiter, with its five moons, down to some of the minor planets a few miles in diameter, and just large enough to become visible by reflected light; and again, downward, of all lesser dimensions to the mere dust-grains which only become visible when the friction on entering our atmosphere with the great velocities due to their planetary motion round the sun ignites and sometimes, perhaps, dissipates them.

We here obtain a new conception of the possible origin of the universe as we now see it (a conception which originated with Professor Tait, and has been forcibly advocated by Lockyer and a few other astronomers), which is, that both the solar system and the stellar universe have arisen from the aggregation of widely-diffused solid particles, molecules, or atoms, whose coming together under the influence of gravitation produces heat, incandescence, and sometimes elemental vaporisation, rather than from a primitive cosmic vapour from which solid masses have been formed by cooling and contraction. Everywhere we become aware of these solid masses of various sizes occupying the spaces around us. The rings of Saturn are composed of such solid particles in a state of unusual condensation. The vast ring of the minor planets indicates probably the existence there of millions of smaller invisible bodies form-

ing a stream of meteors, analogous to some of those which cross our orbit, but which are composed of much smaller bodies since none of them are independently visible. Then we have the comets, consisting of a dense swarm of such meteors whose frequent collisions, due to tidal disturbance as they approach the sun, may produce the luminous gases indicated by their spectra.

Comets' tails, which are known to be formed of minute solid particles, afford us positive proof that the inter-planetary spaces contain no gaseous medium, however thin; because, if there were any such medium, the enormous velocity with which these particles are driven off would certainly lead to their vaporisation. We find proof of matter in the solid state everywhere, but of gaseous matter only where it can have been produced by the heat due to the collision of solids. This subject will be further illustrated when we have discussed our recently acquired knowledge of the stellar universe which forms the subject of a later chapter.

CHAPTER XIII

THE SUN'S NATURE AND CONSTITUTION

"In thyself well might'st thou trust,
  God of ancient days, O Sun!
All thy sequent stars the dust
  From thy whirling car-wheels spun;
All that lies within thy seeing
From thy golden smile has being."
F. T. PALGRAVE.

THE mass of accurate knowledge we now possess as to the physical condition and essential nature of the sun is wholly due to the workers of the nineteenth century, and almost so to those of the latter half of it. During the early period the phenomena to be explained had come to be generally recognised, while only during the later portion, by the use of the spectroscope, were they partially explained. As the stars are really suns, all accurate knowledge of the conditions of the stellar universe must be based upon a knowledge of the sun's nature founded upon a correct interpretation of the phenomena it presents to us. We must therefore devote a few pages to an account of results arrived at by the careful study of the sun's surface and immediate surroundings.

In the early part of the century opinion as to the nature of the sun was mere guesswork, as shown by the extraordinary idea, supported even by Sir William Herschel, that the sun *might* be a globe like the earth with vegetation and inhabitants, surrounded by a glowing atmosphere which alone we see, while the real surface was protected by clouds or vapours. This was partly founded on the

appearance of sun-spots as vast breaks in the luminous covering allowing the cool surface to be visible. The fact that the sun's density is only one-fourth that of the earth, or less than one and a half times that of water, demonstrates, however, that it cannot be solid, since the force of gravity at its surface being twenty-six and a half times that at the earth's surface, the materials of a solid globe would be so compressed that the resulting density would be at least twenty times greater instead of four times less than that of the earth. All the evidence goes to show that the body of the sun is really gaseous, but so compressed by its gravitative force as to behave like a liquid. A few figures as to the amount of light and heat emitted by the sun and its vast dimensions will enable us better to understand the phenomena it presents and the interpretation of those phenomena.

Proctor estimated that each square inch of the sun's surface emitted as much light as twenty-five electric arcs; and Professor Langley has shown by experiment that it is 5300 times brighter, and eighty-seven times hotter, than the white-hot metal in a Bessemer converter. The actual amount of solar heat received by the earth is sufficient, if wholly utilised, to keep a three-horse-power engine continually at work on every square yard of the surface of our globe. The size of the sun is such that, if the earth were at its centre, not only would there be ample space for the moon's orbit but sufficient for another satellite 190,000 miles beyond the moon, both revolving inside the sun. The mass of matter in the sun is 745 times greater than that of all the planets combined, hence the powerful gravitative force by which they are all retained in their distant orbits.

What we see as the sun's surface is the photosphere or outer layer of gaseous or partially liquid matter kept at

Fig. 88.—A Sun-Spot photographed

a definite level by the power of gravitation. The photosphere has a granular texture implying some diversity of surface or of luminosity, although the even contour of the sun's margin shows that these irregularities are not on a very large scale. This surface is apparently rent asunder by what are termed sun-spots, which were long supposed to be cavities showing a dark interior. These appear to be black, but around their margins is a shaded border or penumbra formed of elongated shining patches crossing and overlapping, something like heaps of straw. Sometimes brilliant portions overhang the dark spots and often completely bridge them over (Fig. 88); and similar patches, called faculæ, accompany spots and in some cases almost surround them.

Sun-spots are sometimes numerous on the sun's disc, sometimes very few, and they are of such enormous size that, when present, they can easily be seen with the naked eye protected by a piece of smoked glass, or better still with an ordinary opera-glass similarly protected. Sun-spots are found to increase and decrease for years together, the maxima recurring after an average period of eleven years, but with no exactness since the interval between two maxima or minima is sometimes only nine, and sometimes as much as thirteen years. What is more interesting is that variations in terrestrial magnetism follow them with great accuracy, as shown in the accompanying diagram (Fig. 89), in which the black line shows the abundance of sun-spots, while the dotted line shows the amount of daily variation of the magnetic needle. Violent commotions in the sun indicated by the sudden appearance of faculæ or sun-spots, or of prominences on the sun's limb, are always accompanied by magnetic disturbances on the earth.

The rotation of the sun affords another proof that the surface we see is not a solid, for, from long-continued

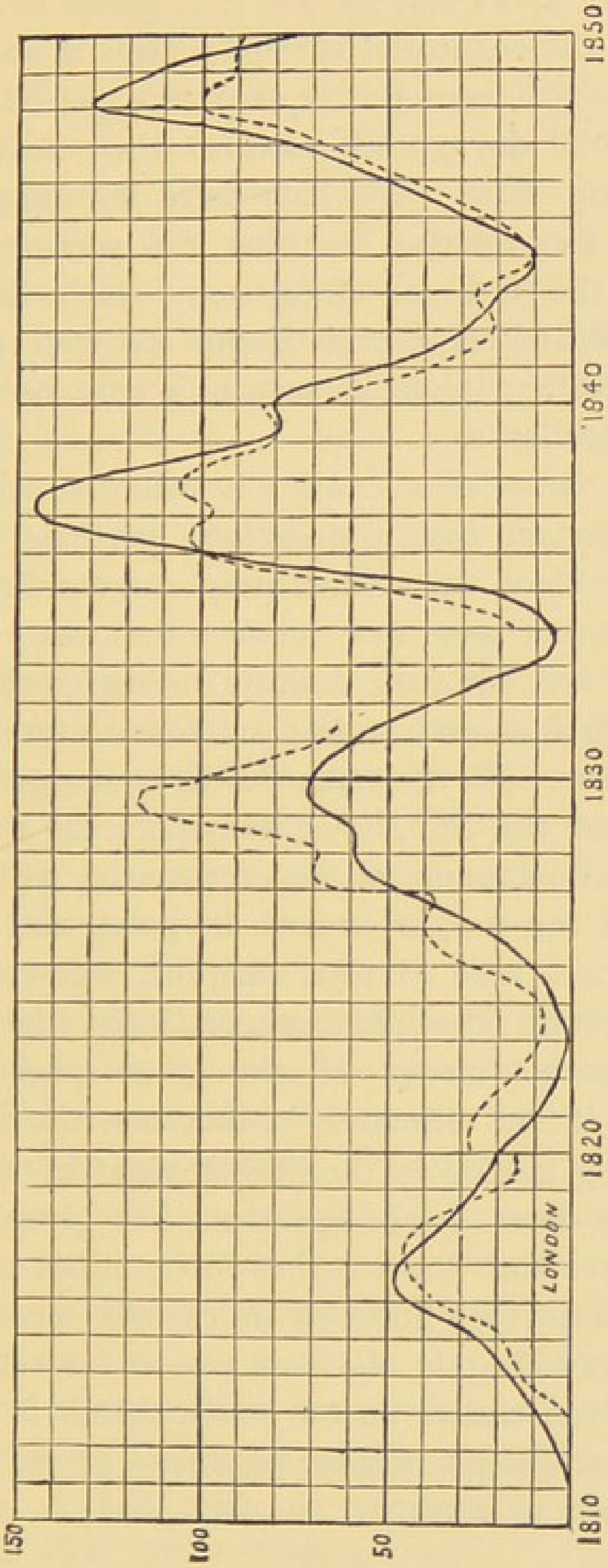


Fig. 89.—Diagram of Sun-Spots and Magnetism

observations of spots and faculæ, it is found to be unequal, so that while the equatorial surface rotates in about twenty-five days, at 30° from the equator the period is twenty-seven and a half days, while towards the poles it increases to nearly forty days. We have here indications that the mass of the sun rotates, but that the surface rotation is affected by the internal circulation which leads to the production of sun-spots and faculæ as well as to those more extraordinary phenomena which only become visible during total eclipses.

The exact nature of sun-spots is still somewhat obscure. It appears certain that the darkest portions are cavities below the level of the immediately surrounding area, but even this does not seem to be always the case. It has been proved, however, by very delicate measurements, that the areas in which sun-spots appear are first elevated above the general surface. Sir Norman Lockyer suggested, in his "Chemistry of the Sun," that sun-spots are really caused by enormous downpours of cooled material which has been driven out of the sun, often near its poles, and which form the prominences seen in total eclipses, this cooled matter breaking through the photosphere, into which it sinks, while the hotter matter of the photosphere gradually spreads over it and ultimately obliterates it. The method of determining motion in the line of sight by the displacement of dark lines in the spectrum has given a proof of both up-rushes and down-rushes in or about sun-spots up to a speed of several hundred miles in a second; but the conditions prevailing in the sun are so far removed from anything we can realise on our earth that it is not easy to explain the various phenomena produced by the tremendous forces evidently at work.

What surrounds the Sun

If we look at the sun through a suitable protective medium, either with the unaided eye or through a telescope, it appears as a globular object with a clearly defined circular boundary line such as is presented by the full moon or any of the larger planets. Outside this circle we see nothing but an undefined glare of light, gradually merging at a moderate distance into the blue of the sky. Yet, though invisible to us under ordinary conditions, the sun is constantly surrounded by a series of luminous appendages of a very marvellous character, and as unlike anything to be seen elsewhere in the heavens as are the beautiful rings of Saturn to anything pertaining to the other planets. These strange and unexpected surroundings only become visible to us on those rare occasions when the sun is totally eclipsed, and, though they were seen by some earlier observers, they were hardly recognised by astronomers as permanent phenomena till the occurrence of a total eclipse which was visible over southern and central Europe on 8th July 1842.

On that occasion Baily, a well-known astronomer, was at Pavia, and as he watched the gradual disappearance of the sun behind the moon's disc he was, as he describes, at the moment of disappearance, "electrified at the sight of one of the most brilliant and splendid phenomena that can well be imagined. For, at that instant, the dark body of the moon was suddenly surrounded with a corona or kind of bright glory similar in shape and relative magnitude to that which painters draw round the heads of saints. . . . I did not expect, from any of the accounts of preceding eclipses that I had read, to witness so magnificent an exhibition as that which took place. . . . Its colour was quite white, not pearl colour, nor yellow, nor red, and the

rays had a vivid and flickering appearance. . . . But the most remarkable circumstance attending the phenomenon was the appearance of three large protuberances, apparently emanating from the circumference of the moon, yet evidently forming a portion of the corona. They had the appearance of mountains of a prodigious elevation; their colour was red, tinged with lilac or purple; perhaps the colour of the peach-blossom would more nearly represent it. . . . Their light was perfectly steady. All were of the same roseate colour, and very different from the brilliant, vivid, white light that formed the corona, but they were of different sizes. . . . The whole of these three protuberances remained visible to the last moment of total obscuration; and when the first ray of light was admitted from the sun they vanished, with the corona, altogether, and daylight was instantaneously restored."

Other observers measured these protuberances, which were found to be about 54,000 miles high. Owing to differences of atmospheric conditions, the more delicately coloured corona was seen to be much larger at some localities than at others. At some places it was seen extended into four vast luminous expansions at four opposite points; and Struve estimated the corona itself to extend nearly to a width equal to the sun's diameter, while the expansions spread out to six times that distance.

Since then every total eclipse has been carefully observed by numerous astronomers, who have visited the remotest parts of the earth for the purpose, and, while these early observations have been confirmed, much more has been ascertained, while the use of the spectroscope has afforded a considerable amount of knowledge as to the causes which underlie the appearances. A brief outline of the facts and conclusions which seem most probable will now be given.

It has been well said that what we commonly term the sun is really the bright spherical nucleus of a nebulous body. This nucleus consists of matter in the gaseous state, but so compressed by its enormous gravitative force as to behave more like a liquid, or even like a viscous solid. About forty of the terrestrial elements have been detected in the sun by means of the dark lines in its spectrum, but it is almost certain that all the elements, in some form or other, exist there. This semi-liquid glowing surface is termed the photosphere, since from it is given out the light and heat of the sun.

Immediately above this luminous surface is what is termed the "reversing layer," or absorbing layer, consisting of metallic vapours only a few hundred miles thick, and, though glowing, somewhat cooler than the surface of the photosphere. Its spectrum, taken at the moment when the sun is totally darkened, through a slit which is directed tangentially to the sun's limb, shows a mass of bright lines corresponding in a large degree to the dark lines in the ordinary solar spectrum. It is thus proved to be a vapourous stratum which absorbs the special rays emitted by each element and forming its characteristic coloured lines, changing them into black lines. But as coloured lines are not found in this layer corresponding to all the black lines in the solar spectrum, it is now held that special absorption must also occur in the next layer, the chromosphere, and perhaps in the corona itself. Sir Norman Lockyer, in his volume on "Inorganic Evolution," even goes so far as to say that the true "reversing layer" of the sun—that which by its absorption produces the dark lines in the solar spectrum—is now shown to be *not* the chromosphere itself but a layer above it, of lower temperature.

Above the reversing layer comes the chromosphere—a vast mass of rosy or scarlet flames surrounding the sun

to a depth of about 4000 miles. When seen during eclipses it shows a serrated waving outline, but subject to great changes of form, producing the prominences already mentioned. These are of two kinds, the "quiescent," which are something like clouds of enormous extent, and which keep their forms for a considerable time; and the "eruptive," which shoot out in towering tree-like flames or geyser-like spouting, and while doing so have been shown to reach velocities of over 300 miles a second, and they subside again with almost equal rapidity. The chromosphere and its quiescent prominences are mainly gaseous, consisting of hydrogen, helium, and coronium, while the eruptive prominences always show the presence of metallic vapours, especially of calcium. Prominences increase in size and number in close accordance with the increase of sun-spots.

Beyond the red chromosphere and prominences extends the marvellous white glory of the corona, which, as has been already described, extends to an enormous distance round the sun. Like the prominences of the chromosphere it is subject to periodical changes in form and size corresponding to the sun-spot period, but in inverse order, a minimum of sun-spots going with a maximum extension of the corona. At the total eclipse of July 1878, when the sun's surface was almost wholly clear, a pair of enormous equatorial streamers stretched east and west of the sun to a distance of 10,000,000 miles, and less extensions of the corona occurred at the poles. At the eclipses of 1882 and 1883, on the other hand, when sun-spots were at a maximum, the corona was regularly stellate with no angular extensions, but of great brillancy (Fig. 90). This correspondence has been noted at every eclipse, and there is, therefore, an undoubted connection between the two phenomena.

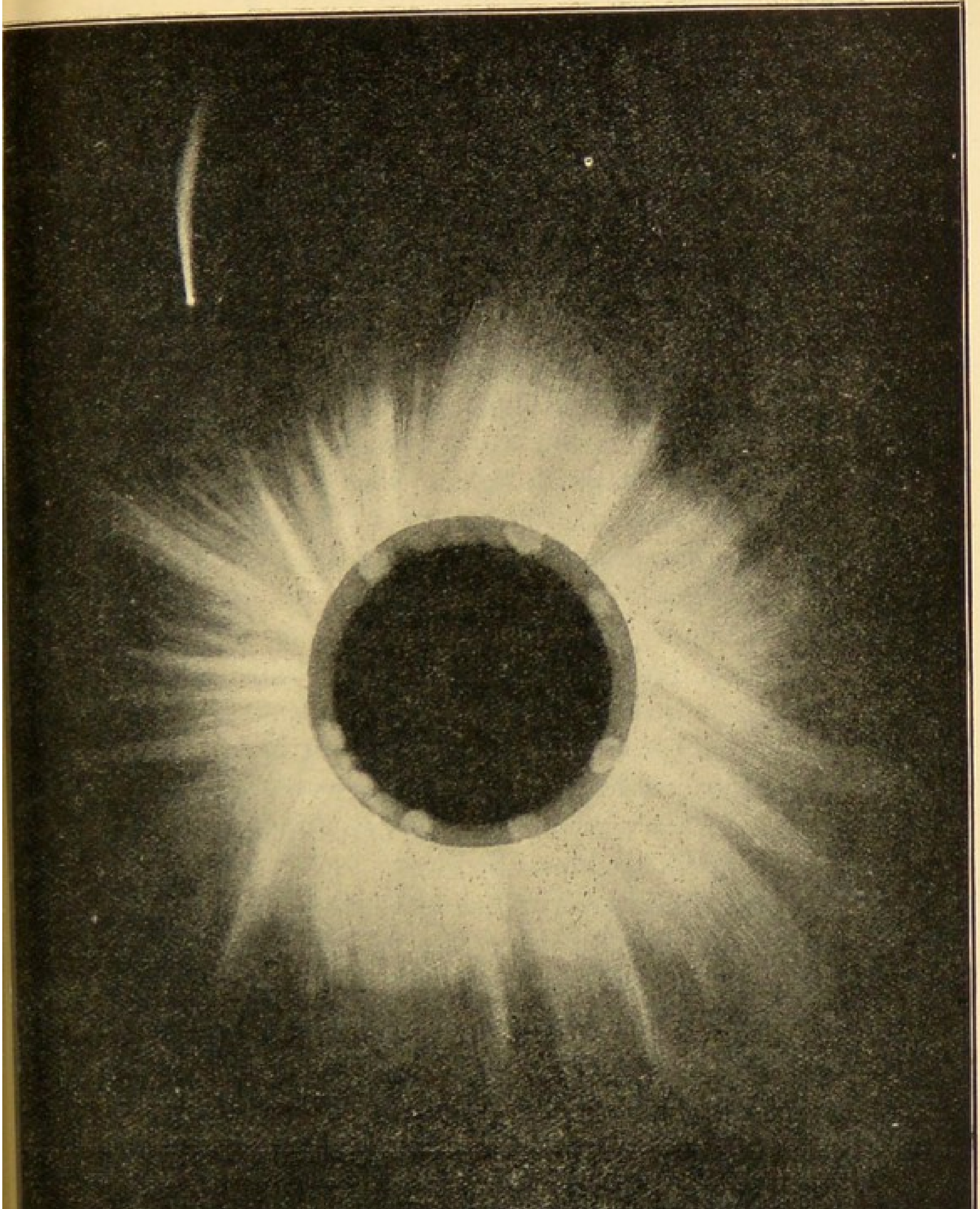


Fig. 90.—The Corona, as seen during the Total Eclipse of 1883

The light of the corona is believed to be derived from three sources—from incandescent, solid, or liquid particles thrown out from the sun, from sunlight reflected from these particles, and from gaseous emissions. Its spectrum possesses a green ray which is peculiar to it, and is supposed to indicate a gas named "coronium"; in other respects its spectrum is more like that of reflected sunlight. The enormous extensions of the corona into great angular streamers seem to indicate electrical repulsive forces analogous to those which produce the tails of comets.

Connected with the sun's corona is that strange phenomenon, the zodiacal light. This is a delicate nebulosity which is seen after sunset in Spring and before sunrise in Autumn, tapering upwards from the sun's direction along the plane of the ecliptic. It has been seen occasionally under very favourable conditions in the eastern sky in Spring 180° from the sun's position, indicating that it extends beyond the earth's orbit. Long-continued observations from the summit of the Pic du Midi show that this is really the case, and that it lies almost exactly in the plane of the sun's equator. It is, therefore, held to be produced by the minute particles thrown off the sun, through those coronal wings and streamers, seen only during solar eclipses.

The careful study of the solar phenomena has very clearly established the fact that none of the sun's envelopes, from the reversing layer to the corona itself, is in any sense an atmosphere. The combination of enormous gravitative force with an amount of heat which turns all the elements into the liquid or gaseous state leads to consequences which it is difficult for us to follow out or to comprehend. There is evidently a constant internal movement or circulation in the interior of the sun resulting in the faculæ, the sun-spots, the intensely luminous photo-

sphere, and the chromosphere, with its vast flaming coruscations and eruptive protuberances. But it seems impossible that this incessant and violent movement can be kept up without some great and periodical or continuous inrush of fresh materials to renew the heat, to keep up the internal circulation, and supply the waste. Perhaps the movement of the sun through space may bring him into contact with sufficiently large masses of matter to continually excite that internal movement without which the exterior surface would rapidly become cool and all planetary life cease. The various solar envelopes are the result of this internal agitation, uprushes, and explosions, while the vast white corona is probably of little more density than comets' tails, perhaps even of less density, since comets not unfrequently rush through its midst without suffering any loss of velocity.

The fact that none of the solar envelopes are visible to us until the light of the photosphere is completely shut off, and that they all vanish the very instant the first gleam of direct sunlight reaches us, is another proof of their extreme tenuity, as is also the sharply defined edge of the sun's disc. The envelopes, therefore, consist partly of liquid or vaporous matter in a very finely divided state driven off by explosions or by electrical forces, and this matter, rapidly cooling, becomes solidified into minutest particles or even chemical molecules. Much of it continually falls back on the sun's surface, but a certain quantity of the very finest dust is continually driven away by electrical repulsion so as to form the corona and the zodiacal light. The vast coronal streamers and the still more extensive ring of the zodiacal light are, therefore, in all probability due to the same causes as, and have a similar physical constitution to, the tails of comets.

As the whole of our sunlight must pass through both

the reversing layer and the red chromosphere, its colour must be somewhat modified by them. Hence it is believed that, if they were absent, not only would the light and heat of the sun be somewhat greater, but that its colour would be a purer white, tending towards a bluish rather than towards the yellowish tinge it actually possesses.

CHAPTER XIV

THE STARS

"The wilder'd mind is tost and lost,
O sea, in thy eternal tide;
The reeling brain essays in vain,
O stars, to grasp the vastness wide!
The terrible tremendous scheme
That glimmers in each glancing light,
O night, O stars, too rudely jars
The finite with the infinite!"

J. H. DELL.

THE Greek philosopher Hipparchus, startled by the appearance of a brilliant new star in the year 134 B.C., forthwith devoted himself to the preparation of a catalogue of all the stars visible in Southern Europe, giving their positions with regard to each other and to the earth's equator, to the number of 1080. He was the first of the great astronomers of the world. The Persian and other Eastern astronomers added somewhat to the accuracy of the older determinations, but the number of observed stars could not be much increased till the telescope was invented, and it was only in the early part of the eighteenth century that Flamsteed, the first Astronomer-Royal, fixed the positions of all the stars visible with his telescopic instruments, and thus recorded 3000 stars in his "British Catalogue." Halley had gone to St Helena in 1677 in order to observe those southern stars which were invisible in England, 341 in number, and these formed an appendix to the British Catalogue.

It was by means of repeated accurate observations of stars that Bradley, in 1728, discovered the minute change

in the apparent position of stars due to aberration of light, and as this only amounts to about 20″, it shows how exceedingly accurate were the observations then made. He also discovered another cause of apparent motion of the heavenly bodies due to nutation, a slight movement of the earth's axis, which describes an ellipse 13.7″ by 18.5″ in diameter in eighteen years. The accurate determination of these apparent motions was an essential preliminary to any knowledge of the real motions or the distances of the stars. Halley was the first to prove that some of the stars had really independent or "proper" motions, which he ascertained by comparing their positions with those given by earlier observers. Arcturus was thus found to be moving at the rate of two seconds a year, and two other bright stars, Sirius and Aldebaran, had similar motions.

The Distances of the Stars

It was only in the nineteenth century that the proper motions of a considerable number of the stars were accurately determined, and that it became possible to attack the far more difficult problem of the distances of the stars with any prospect of success. But after years of careful observation during the first half of the century definite results were obtained in three cases, while up to the end of the century about sixty had been measured with tolerable certainty.

The measurement of stellar distances is the most difficult determination in practical astronomy, and a brief explanation of the method of effecting it must be given. Inaccessible objects at a distance can be measured with considerable accuracy if we have an instrument for measuring angles, such as a sextant or theodolite, and a measured base not

too small as compared with the distance of the object. Thus, if a church spire is about half-a-mile off, and we are in a garden 200 feet wide, we can easily measure the distance of the spire within a few feet.

In this diagram we have measured a base line 184 feet

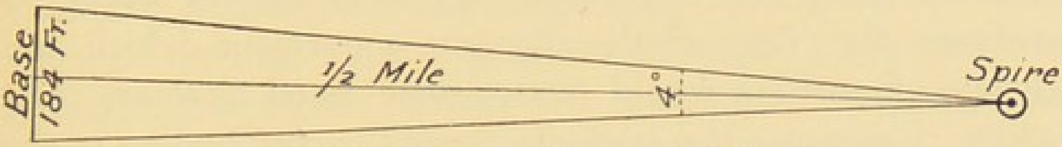


Fig. 91.—Measurement of inaccessible distances.

long, as shown, marking the ends by upright sticks. If now we measure accurately the angle at each end of the base formed by the line of the base and the line to the spire, we shall find each angle to be two degrees less than a right angle, or 88°. Hence, as the three angles of a triangle are equal to two right angles, if we could stand at the centre of the tower under the spire, and had a clear view of the two sticks at the ends of our base line, the angle measured there between these sticks would be four degrees. By means of mathematical tables of sines, etc., or even by drawing a diagram on a large scale, the distance can be found to be 2640 feet, or exactly half-a-mile. It is evident that if the distance of the spire were ten or twenty miles instead of half-a-mile, it would be much more difficult to measure the distance from the same base, because the two angles from its ends would be so nearly right angles that it would require a very accurate instrument to measure them, and the very smallest error would increase or diminish the distance enormously. But in attempting to measure the distance of the stars the angles are excessively small, and there are besides many other difficulties that would seem to render the measurement impossible.

The base line used for the purpose is the whole diameter of the earth's orbit, or about 183,000,000 miles. Every

six months we reach opposite positions in this orbit, and therefore see the stars from a different point of view. Yet this enormous change of place causes no change whatever in the relative positions of most of the stars, even when examined with very powerful telescopes, — hence their distance must be enormously great. But in order to measure the very small apparent movement which the change of position would cause, some fixed direction from which to measure the angles is needed corresponding to the line between the two sticks at the ends of the base line. Now, in the whole heavens there is only one fixed direction known, that of the earth's axis. If the earth were a perfect solid sphere rotating as it does now, the direction of the pole would be constant, but being a spheroid the attraction of the sun and moon on the protuberance at the equator leads to a very slow change of direction. The axis describes a very minute circle round the true pole in eighteen years, and it also very slowly changes its direction so as to make a complete revolution of the heavens in 24,450 years. These motions, however, are now known with great accuracy, and can be allowed for; but then comes another difficulty in the motions of the stars themselves, which it has long been known are not absolutely fixed but have each their proper motion—that is, they really shift their positions in the heavens, though very slowly. The proper motions of several hundreds have now been determined, and are found to vary from about seven seconds a year down to so small a fraction of a second as to be imperceptible except after very long intervals. Yet another difficulty arises from the fact that our sun, with its planets, is also moving in a direction which has been roughly but not accurately determined, so that any change in the apparent position of a star may be partly due to this motion.

The proper motion of the stars, however, has given astronomers a guide to those which are probably nearest to us, and which, therefore, can be most easily measured, and the method of measurement must now be indicated. If, while sailing along the coast, we observe the trees, churches, houses, and other stationary objects on the land, we shall see that those nearest to us appear to move more quickly than those farther off, while the most distant appear to be almost stationary. In the same way, if we are on a hill near the coast, and observe sailing boats and ships at various distances, those nearest to us will appear to move quickly, those farther off more slowly, while those on the extreme horizon will appear almost motionless for a considerable time; yet all may be moving at about the same rate. So with the stars. If all are really moving at about the same rate, those nearest to us will appear to move fastest, while only those in the extreme distance will appear not to move at all. Now, if we wanted to measure the distance of any of these vessels by means of a very short base line on shore, we should, of course, choose those which appeared to move fastest, because they would be nearest to us.

At first it was thought that the brightest stars were nearest to us, but the very brighest stars are found to have on the average very small proper motions, while the stars with greatest proper motions are often quite small ones. And the results of such measurements as have been made confirm this, there being no close correspondence between the brilliancy and the distance of the stars.

The method of measuring the distance of some of the stars will now be better understood. The difficulty of obtaining an absolutely fixed line of direction in the heavens, together with the instrumental inaccuracies that inevitably occur in measuring large angles by means of instruments

having divided circles, has led to the adoption of what is termed the differential method. A star is chosen which has a considerable proper motion, and which has several other stars apparently close to it, but which have either no proper motion or an excessively small one. If now the distance of the first star from each of the others is measured at periods six months apart, and if the change of position of the first star is found to be almost the same when determined by each of the other stars, there will be every probability that the displacement is really due to our different point of view, when at opposite positions in the earth's orbit, and, therefore, at the two ends of a base line nearly 190,000,000 miles long.

In order to measure small angles with the greatest accuracy an instrument has been invented termed the heliometer, so named from having been first used in measuring positions of spots, etc., on the sun's disc. It was also applied to measurements of close double-stars, and is now found to be the most reliable instrument for determining the parallax of fixed stars, and hence their distances. It consists of an equatorial telescope of considerable size, the object-glass being cut across into two equal parts, which are so connected that by means of a very fine screw they can be made to slide along the line of junction, and the angular separation of the objects observed can be thus determined far more accurately than with any other instrument. Under favourable conditions an angle of $\frac{1}{20}$ of a second can be measured with some precision. This amount is marvellously small. At half-a-mile distance an object 44 feet wide—the size of a moderate house—subtends an angle of one degree; an object a little less than 9 inches wide at the same distance will be one minute wide, and to subtend an angle of only one second an object must be less than $\frac{1}{6}$ inch wide—that is, much less than the thickness of

an ordinary lead-pencil and about equal to that of a rather thin pen-holder. But one-twentieth of this is less than the thickness of the thinnest pin or needle used for ordinary purposes, so that such a pin could not only be seen, but its thickness approximately measured by this wonderful instrument, at a distance of half-a-mile.

What is termed the "parallax" of a star is the angle which the line joining the centres of the earth and sun would subtend when seen from the star. This has been determined with a fair degree of certainty in the case of sixty-two stars, and of these only two have so large a parallax as a quarter of a second; while in the majority of cases it lies between one-tenth and one-twentieth of a second, while many show a still smaller parallax or none at all. It must be understood that none of these results depend on a single measurement only, but usually on scores or even hundreds, and often made by observers in various parts of the earth. The close approximation of the results of series of measurements in different years or by different observers, shows that the observations may be trusted, while by taking the means of all the observations a greater degree of accuracy is attained than would otherwise be possible.

The distance of the stars in miles may be ascertained by multiplying 93,000,000 miles by 206,265 and dividing the result by the parallax in seconds. Hence a star having the rather large parallax of one-tenth of a second would be 191,826,450,000,000 miles distant from us, or about 192 millions of millions of miles. Such huge figures are, however, inconvenient, and give us only the idea of inconceivable remoteness, while they are very difficult to remember. Astronomers, therefore, generally use as a standard what is termed the "light-journey," or the number of years light takes to reach us from the star in

question. This can be found by dividing the number 3.258 by the parallax. Hence the stars having one-tenth of a second parallax are seen by us about thirty-two and a half years after the light left them. Such figures as these can be remembered with comparative ease. The light from Sirius, the brightest star in the heavens, reaches us in about twelve and a half years, while that from the small star, 61 Cygni, would reach us in about seven years.

Having thus determined the distances of a considerable number of stars, and knowing also their proper motions year by year, we are in a position to calculate their real motions at right angles to our line of sight. Arcturus has thus been shown to move at the rate of at least 200 miles a second, but this is exceptionally rapid, rates of from 5 to 20 miles a second being much more frequent. The motion of the earth in its orbit is about 9¼ miles per second.

The Sun's Motion in Space

When it was found that many stars had real motions, and the analogy of our sun to the stars was perceived, it was thought highly probable that the sun also was moving onward, and it became important to ascertain in what direction it was going, and, if possible, the rate of its motion. Sir William Herschel was the first to attempt a determination of this direction, and similar attempts have been made throughout the century, with a general agreement of results, though no approach to accuracy can be yet made. The method pursued is a very simple one. If we are slowly moving towards a number of stationary objects, such as rather widely scattered trees on a plain, it is evident that

those towards which we are moving will gradually appear to open out, while those we are moving directly away from will seem to come closer together as we get farther from them. Those to the right and left of us, however, will not change their relative positions unless they are at very unequal distances, and the change will be similar in these two directions.

By observing all the stars which have large proper motions, and which, therefore, are presumably about the same distance from us, such an opening out or widening of distances in one direction, and slight contracting of distances in the opposite direction, can be detected. Herschel placed the direction of motion towards the constellation Hercules, but more recent observations on a larger number of stars whose proper motions have been determined, place it in the adjacent constellation Lyra, and about 2° from the brilliant star Vega. It is evident that this actual motion of the sun in a definite direction must be allowed for in all determinations we make as to the actual motions of stars deduced from their distances and proper motions; while the problem is still further complicated by the fact that stars which appear to be at absolute rest may really be moving towards us or away from us quite as rapidly as others are moving in directions across our line of sight. But, fortunately, a method has now been discovered of measuring actual motion towards or away from us without regard to the remoteness of the moving object; and this discovery has so greatly increased our means of penetrating the secrets of the stellar universe that it may be considered to be not only one of the most remarkable but also one of the most important among the numerous minor discoveries of the nineteenth century. It is one more added to the numerous triumphs of the spectroscope used in connection with photography, and a short description of

how this has been effected will be perhaps useful to many of my readers.

Measurement of Motion in the Line of Sight

In order to understand how this is possible, we have to refer to the wave-theory of light; and the analogy of other wave-motions will enable us better to grasp the principle on which these calculations depend. If on a nearly calm day we count the waves that pass each minute by an anchored steamboat, and then travel in the direction the waves come from, we shall find that a larger number pass us in the same time. Again, if we are standing near a railway, and an engine comes towards us whistling, we shall notice that it changes its tone as it passes us; and as it recedes the sound will be very different, although the engine is at the same distance from us and travelling at the same speed as when it was approaching. Yet the sound does not change to the ear of the engine-driver, the cause of the change being that the sound-waves reach us in quicker succession as the source of the waves is approaching us than when it is retreating from us. Now, just as the pitch of a note depends upon the rapidity with which the air-vibrations reach our ear, so does the colour of a particular part of the spectrum depend upon the rapidity with which the ethereal waves which produce colour reach our eyes; and as this rapidity is greater when the source of the light is approaching than when it is receding from us, a slight change of colour and also shifting of the position of the dark lines of the spectrum will occur, as compared with their position in the spectrum of the sun or of any stationary source of light, if there is any

motion sufficient in amount to produce a perceptible shift. That such a change of colour would occur was pointed out by Professor Doppler of Prague in 1842, and it is usually termed the Doppler principle; but as the changes of colour were so very slight as to be impossible of measurement it was not thought to be of any practical importance in astronomy. But when the dark lines in the spectrums were carefully mapped and their positions determined with minute accuracy, it was seen that a means of measuring the changes produced by motion in the line of sight existed, since the position of any of the dark or coloured lines in the spectra of the heavenly bodies could be compared with those of the corresponding lines in the solar spectrum, or produced artificially in the laboratory. This was first done by Sir William Huggins in 1868, who, by the use of a very powerful spectroscope constructed for the purpose, found that such a change of position of the spectral lines did occur in the case of many stars, and that their rate of motion towards us or away from us—termed the radial motion—could be calculated. As the actual distance of some of these stars has been measured, and their change of position annually (their proper motion) determined, the additional factor of the amount of motion in the direction of our line of sight completes the data required to fix their true line of motion among the other stars.

The accuracy of this method under favourable conditions is very great, as has been proved by those cases in which we have independent means of calculating the real motion. The motion of Venus towards or away from us can be calculated with extreme accuracy for any period, being a resultant of the combined motions of the planet and of our earth in their respective orbits. The radial motions of Venus were determined at the Lick Observatory in

August and September 1890, by spectroscopic observations and also by calculation, to be as follows:—

	BY OBSERVATION	BY CALCULATION
Aug. 16th.	—7.3 miles per second	—8.1 miles per second
„ 22nd.	—8.9 „	—8.2 „
„ 30th.	—7.3 „	—8.3 „
Sept. 3rd.	—8.3 „	—8.3 „
„ 4th.	—8.2 „	—8.3 „

showing that the maximum error was only one mile per second, while the mean error was about a quarter of a mile. Another proof of the value and the accuracy of this method of observation has been given when describing the nature of Saturn's rings in the last chapter. (*See* page 243.) Owing to the greater difficulty in observing the spectra of stars, the accuracy in their case is probably not quite so great. This has also been tested by observations of the same star at times when the earth's motion in its orbit is towards or away from the star, whose apparent radial velocity is, therefore, increased or diminished by a known amount. Observations of this kind were made by Dr Vogel, Director of the Astrophysical Observatory at Potsdam, showing, in the case of three stars, of which ten observations were taken, a mean error of about two miles per second.

The same observer, from his study of the spectra of the variable star Algol, has been able to determine, by the application of Kepler's laws, that both the visible star and its dark companion are somewhat larger than our sun, though of less density; that their centres are 3,230,000 miles apart, and that they move in their orbits at rates of 55 and 26 miles per second respectively; and this information, it must be remembered, has been gained as to objects the light of which takes about forty-seven years to reach us!

So striking are these results, and so rapid has been the increase in the delicacy and trustworthiness of the observations, that the President of the Royal Astronomical Society, in an address delivered in 1893, contemplated the possibility that, by still further refinements in the application of the spectroscope, the most accurate measures of the rate of motion of our earth in its orbit, and, therefore, of the distance of the sun, might be deduced from observations of stars which are themselves so remote as to be beyond our powers of measurement.

Returning to the case of the stars: we have now ascertained for several of them the three elements that enable us to determine their position and motion in space. These are (1) their distances from us; (2) their angular displacement in the heavens, or "proper motions"; (3) the actual rate of their motions towards or away from us, usually termed motion in the line of sight, or more briefly, "radial motion." From these three data the real motion of a star in space can be determined both as to speed and direction, on the supposition that the solar system is at rest; but as we are now satisfied that this is not the case, but that it is moving in a definite direction, this introduces another correction which requires also that we know the rate of its motion. At present the data for this determination are very scanty, but they will increase as the distances of a larger number of stars are measured. In the meantime it has been estimated at about 10 miles per second. In the case of very few stars have all the three elements been carefully determined, but the results seem to show an average motion from one and a half to twice the amount of the rate of solar motion given above.

Variable Stars

There is no definite statement showing that the ancient astronomers were acquainted with the variability in brightness or the regular appearance and disappearance of certain stars; but the fact that one of these stars was named Mira, "the wonderful," and another, Algol, "the Dæmon," seems to show that they had observed these strange peculiarities.

The earliest recorded observation of a variable star was made by David Fabricius in 1596. On 13th April of that year he noted the star Mira in the constellation of the Whale—Omicron Ceti—to be of the third magnitude, but in the following year it had disappeared, and he did not see it again till 1603. It was afterwards watched by many astronomers, and it was found that it appeared at intervals of about eleven months, but only remained visible for a few weeks, and did not always appear of the same brightness, sometimes being almost of the second magnitude, while at others it did not exceed the fifth. As with most variable stars, it attains its greatest brilliancy quickly and then fades away more slowly. It has now been carefully watched for many years, and is found to have a period of 331 days and a few hours. It usually remains at its greatest brightness for about a fortnight. Its light then decreases till at the end of three months it becomes invisible to the naked eye, and remains so for five months, when it reappears, and in about two and a half months again attains its maximum. During its period of disappearance it can still be seen in a good 3-inch telescope as a star between the ninth and tenth magnitude.

Another variable star visible to the naked eye is Beta Lyræ, which has a period of twelve days, twenty-one and three-quarter hours. At its maximum brightness it is

about 3.4 magnitude, but it has two minima at intervals of six and a half days of unequal brightness, one being 3.9, the other 4.5 magnitude. This star has been carefully studied in America with some very striking results. By the doubling of certain of its spectral lines Professor Pickering has proved it to consist of two bodies both luminous and exceedingly close to each other, so much so that their gaseous atmospheres must almost intermingle. The slight but continuous variation of their brightness is thus readily explained. One is about half as bright as the other, and they revolve in a plane directed nearly towards us, and thus eclipse each other alternately. The unequal minima are produced at the period of these eclipses when either the more brilliant or the less brilliant are nearest to us; while when they open out so as to be really side by side but so close as to appear one star even with the best telescopes, they have a maximum of brightness. Their time of revolution, together with their actual rate of motion determined spectroscopically, has, enabled astronomers to ascertain their dimensions and mass. The larger is more than nine times the mass of our sun, the smaller about half as much, and the distance between the centres of the two bodies is about 30,000,000 miles. The mean density of the system is a little less than that of air.

We will now give a somewhat detailed account of the most interesting of all variable stars yet discovered. The star Algol in the constellation Perseus is one of the most remarkable in the heavens, since it varies in brilliancy to an amount that can be easily observed with the naked eye, and the change occurs with the most perfect regularity and in the short space of two days and twenty-one hours. It is usually seen as a star of the second magnitude, and it remains so without any change for fifty-nine hours. It then begins to lose brilliancy, and in the short period of

about four and a half hours becomes of the fourth magnitude. It then gets brighter, and in about four and a half hours more regains its original brilliancy. Owing to this strange behaviour, probably, it was named the Dæmon by the ancient astronomers; but the time of variation was not accurately noted till 1783, when the English astronomer Goodricke wrote upon it in the Philosophical Transactions, and suggested that its variation of brilliancy was probably caused by a dark companion revolving round it and partially obscuring it owing to the plane of its orbit being nearly in a line with the earth.

It was not, however, till 1880 that a special study of this star was made by Professor Pickering of the Harvard Observatory. The time of revolution of the supposed dark star around the common centre of gravity, together with the time of partial obscuration of the light of Algol, furnished data from which an estimate could be made of the comparative sizes of the two bodies and their distances apart in proportion to these sizes. His conclusions were that the dark companion was probably about three-fourths of the diameter of the bright star, and that the diameter of its orbit would be about four and a half times that of the diameter of Algol itself. But as both stars must necessarily revolve around their common centre of gravity, it followed that Algol, being the largest, would, supposing both to be of nearly equal density, also revolve in a smaller orbit.

These conclusions were dependent solely on the laws of motion under gravitation and the known periods of revolution and obscuration; but the spectroscope afforded the means of ascertaining the actual speed in miles per second of the bright star, because its plane of revolution being directed towards the earth, it would be moving towards us when at one extremity of a diameter of its

orbit at right angles to that direction and away from us when at the other extremity, and this change of motion would occur every thirty-four and a half hours on the principle already explained. The observations to determine this point were made by Professor Vogel at the Potsdam Observatory in 1888 and 1889, with the result that it was found to be moving in its orbit at the rate of 26 miles in a second.

With this rate of motion actually measured, and the comparative sizes and distances of the pair of stars, as estimated by Professor Pickering, it was found that both Algol and its dark companion are somewhat larger than our sun, that their centres are 3,230,000 miles apart, and that the dark companion moves in its orbit at the rate of 55 miles a second. The final conclusions of Professor Vogel as to these stars are as follows:—

Diameter of Algol	1,061,000 miles
„ of dark companion	830,000 „
Distance between their centres	3,230,000 „
Orbital speed of Algol	26.3 miles per second
„ „ of companion	55.4 „ „
Mass of Algol	4/9 mass of our sun
„ of companion	2/9 „ „

When it is considered that these figures relate to a pair of stars, only one of which has ever been seen, that the orbital motion even of the visible star cannot be detected in the most powerful telescopes, and that the distances of these objects are so great that light, notwithstanding its enormous velocity, requires about forty years to reach our eyes, the great results of spectroscopic observation will be better appreciated. But besides the marvel of such a discovery, the facts discovered are themselves extremely marvellous. All that we had known of the stars till the last score of years had indicated that they

were at great distances from each other. This must be the case even with close double stars, owing to their enormous distances from us. The average distance of stars of the first magnitude is supposed to be about 80 millions of millions of miles. The closest double stars are about half-a-second apart, and at the distance given above they would be really more than 1,500,000,000 miles from each other, or about the same as that of Uranus from the sun. But in the case of Algol and its companion (and also in that of Beta Lyræ) we have two bodies, both larger than our sun, yet with a distance of only 2¼ millions of miles between the surfaces, not much more than the diameter of the larger of the two.

At such a comparatively small distance their atmospheres, if they possess any, must almost certainly intermingle, and the enormous friction thus caused must so reduce their orbital motion as to render it certain that they must be approaching each other, and that they will at no very distant period coalesce into a single star. A reduction of the period of revolution has actually been noticed, but it is said to amount to only about eight seconds since the time of Godericke a century ago. His observations, however, were probably not sufficiently accurate to determine this, and future observations may show whether the diminution of period is still going on at an increased rate.

It is a suggestive fact that a Persian astronomer in the tenth century calls Algol a red star, while it is now white, or somewhat yellowish. This also would imply an increase of temperature such as would be caused by increasing proximity, with friction of intermingling atmospheres or appendages similar to our sun's corona.

It will be observed that of the three variable stars described the first had a period of nearly a year, while the other two completed their changes in a few days. These

correspond to the two groups of long period and short period variables into which astronomers now divide these stars, and the following list given by Professor Simon Newcomb shows how many of each kind had been discovered almost down to the end of the century:—

Variables with a period less than 50 days	63	stars.
Between 50 and 100 days	6	,,
,, 100 ,, 150 ,,	9	,,
,, 150 ,, 200 ,,	18	,,
,, 200 ,, 250 ,,	29	,,
,, 250 ,, 300 ,,	40	,,
,, 300 ,, 350 ,,	44	,,
,, 350 ,, 400 ,,	44	,,
,, 400 ,, 450 ,,	18	,,
,, 450 ,, 500 ,,	6	,,
,, 500 ,, 550 ,,	1	,,
,, 550 ,, 600 ,,	1	,,
,, 600 ,, 650 ,,	1	,,

This table shows a great preponderance of variable stars having periods between two hundred and four hundred days, decreasing in numbers for both less and greater periods. Those of very short period, however, are much more numerous than the average in the first division comprising those under fifty days, there being eight having periods of less than one day and forty with periods between one and ten days, leaving only fifteen with periods between ten and fifty days. It is also stated that those having periods of less than one day are rapidly increasing in numbers with the more thorough search now being made, so that these interesting objects really can be grouped into the two classes of short and long period variables, with comparatively few connecting links.

The most rapidly changing variable known is U. Pegasi, which has a period of nine hours, but a maximum and a minimum occur every four and a half hours, the maxima being equal, while the successive minima are slightly un-

equal. In this case it is believed that two fluid bodies are really connected and revolve together, and this seems to be the only possible explanation of the very short period variables.

There are many irregularities and exceptional features in some of these variables stars which cannot yet be explained; and as new variables are continually being discovered there will be ample work during the twentieth century both for the observers of these curious stars and for the interpreters of the many strange phenomena they present.

Double and Multiple Stars

Double stars is the term applied to those stars which appear single to the naked eye or when observed in a small telescope, yet when viewed with a higher power are seen to consist of two stars very close to one another. Such stars were first noticed by Herschel towards the end of the eighteenth century, and he found them so unexpectedly numerous that, by 1784, he had catalogued more than 700. The fact of their abundance rendered it certain that all of them could not be mere "optical pairs"—that is, stars at very different distances from us which appear double merely because they happen to lie almost exactly one behind the other from our point of view. But it was not till 1802 that he actually proved their mutual revolutions round a common centre of gravity, so that the discovery of the real nature of double, triple, and multiple stars, whether telescopic or spectroscopic, is the product of the nineteenth century.

Struve of Dorpat carried on Herschel's work, first confirming his observation of the motion of the companion of Castor, and thereafter searching the northern heavens,

which added more than two thousand to the previously known double and multiple stars (reckoning each component separately), and in every case he fixed their relative position so that any movement of revolution could be easily detected. The extraordinary abundance of these double stars is shown by the fact that about one in forty of all stars down to the ninth magnitude are found to be double, while among comparatively bright stars the proportion of doubles is about one in twenty.

During this scrutiny it was found that sometimes one of a close pair of stars was itself double, and more rarely that both were so, showing that systems of three or four connected stars, and sometimes even of a greater number, were not uncommon, Struve himself having observed 124 such.

About a thousand systems of double or multiple stars are now known, but the exact orbits of less than a hundred have yet been determined, as many years' observation are often required before any change of position can be detected. It was long since suggested that when two or more stars near each other had the same proper motion they must be in some way physically connected, and it was soon found that many pairs and small groups of stars, far beyond the limits of distance of those usually classed as doubles, had this community of motion. The beautiful group of the Pleiades, of which six can be seen with the naked eye while the telescope shows about sixty which have been catalogued, forms one of these systems. Many of them have been carefully observed for more than a century, during which period they have moved through a space of seven seconds, all moving exactly together and in the same direction. Hence it is concluded that this is a true connected star-cluster. In other cases two or three stars beyond the limits of distance of true binaries—the

term now applied to those that revolve round a common centre of gravity—yet seem to move strictly together; and these have now become so numerous that it is believed a considerable proportion of all stars—perhaps one-third or one-fourth—are really the components of pairs or systems. Thus from simple pairs of stars revolving round a common centre we pass on, by insensible gradations, to those vast clusters of stars which form the most impressive objects in a good telescope, and which, when we consider their distance and the space they must occupy, may be looked upon as being almost independent universes.

Double stars vary greatly in their periods of revolution. One of the most rapid yet known is Kappa Pegasi, which has a companion only a quarter of a second distant from it and only visible in the very finest telescopes. This pair complete a revolution in about eleven and a half years. One other star, Delta Equulei, has very nearly the same period; while three others with periods of nineteen, twenty-two, and twenty-four years make up the five shortest yet known.

A very interesting double is Sirius, the most brilliant star in the heavens, because the existence of a companion was predicted from its irregular proper motion many years before its discovery in 1862. Thirty years' observation has shown that its period is nearly fifty years. The greatest angular diameter of the orbit is only ten seconds—the least three seconds—the orbit being seen obliquely; and the brilliancy of Sirius is so great that the small companion—only of the tenth magnitude—is quite invisible even in the best telescopes when it is nearest to its primary. The accompanying diagram (Fig. 92) gives the observed positions of the small star from 1862 to 1890, with the elliptical orbit that best agrees with them. Although the

difference in brilliancy is so great, these stars do not differ

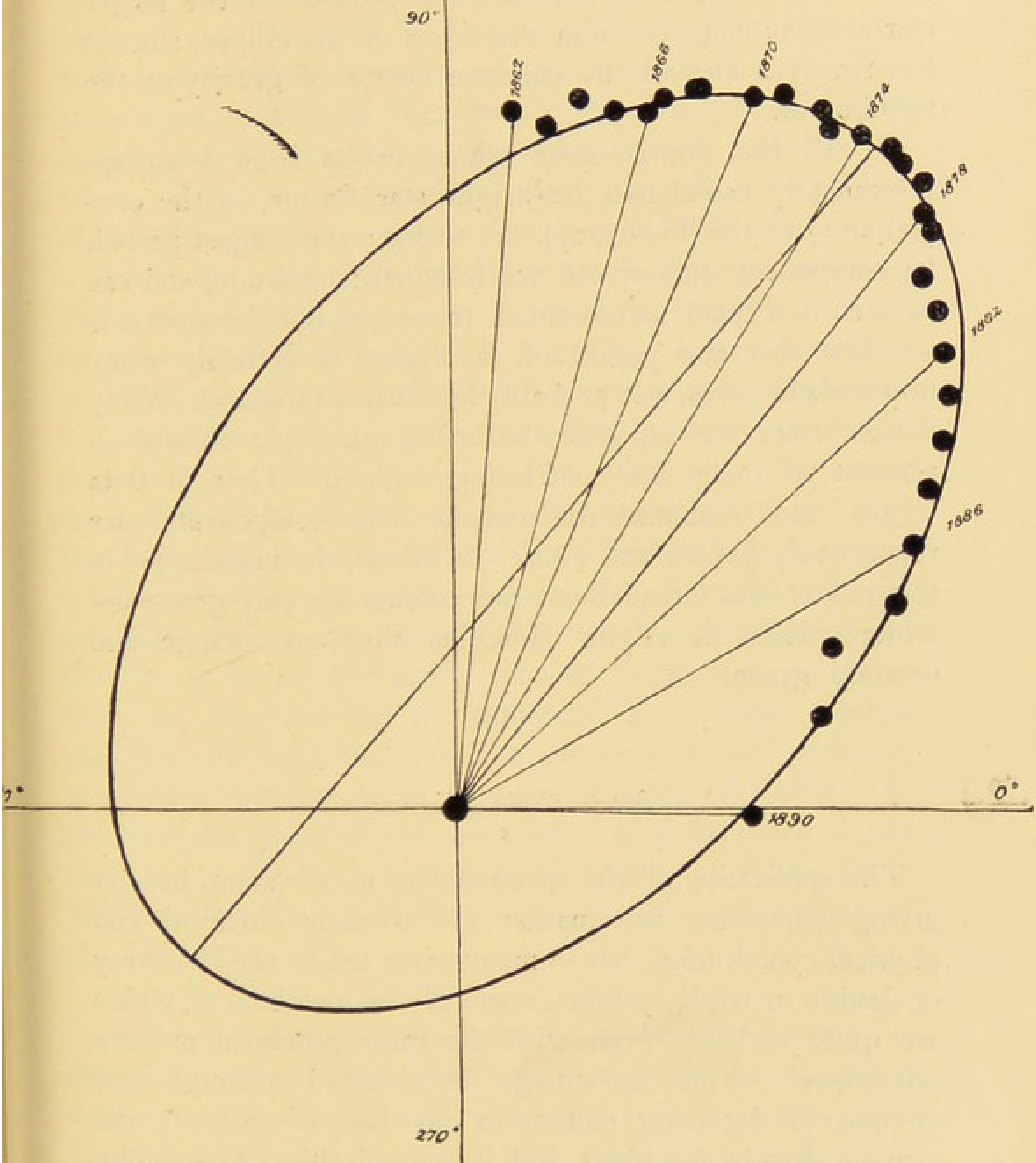


Fig. 92.—Diagram showing the Orbit of the Companion to Sirius

nearly so much in size, the period of revolution with the distance apart as deduced from the measured parallax of

Sirius indicating that the companion has about half the mass of Sirius. This explains the position of the larger star at some distance from the focus of the ellipse, since it too revolves around the common centre of gravity of the two bodies.

Of all the double stars whose orbits have been approximately calculated the bright star Castor, in the constellation of the Twins, appears to have the longest period. Its component stars are of nearly equal magnitude, and can be seen in a small astronomical telescope, but the motion is so slow that the period of revolution is certainly many hundreds of years, but probably less than a thousand. Many double stars are especially beautiful telescopic objects on account of their fine contrasting colours. Thus in Beta Cygni and Gamma Andromedæ the components are respectively yellow and blue. In Mizar, the middle star in the tail of the Great Bear, the colours are pale green and white; while in Alpha Hercules they are orange and emerald green.

Spectroscopic Binaries

The application of the spectroscope to the stars, besides giving important information as to their chemical and physical constitution, has in many cases led to the discovery of double or triple systems, some of the members of which are quite invisible even with the most powerful modern telescopes. This knowledge is obtained through the method of detecting motion in the line of sight in the manner already described, and it is applicable to two quite distinct classes of invisible doubles. The first class includes those cases of dark companions to bright stars the plane of whose orbits is either directly towards us or has a

considerable obliquity. In these circumstances it is evident that the bright star during its revolution around the centre of gravity of the pair will at its greatest elongation be moving alternately towards us and away from us. The other class includes all the cases in which a pair of bright stars are so close together that no telescope can separate them; but the spectroscope can often do so. Some illustrations of these methods will now be given.

About the same time that Professor Vogel was studying the variable star Algol he made a remarkable set of observations as to the brilliant star Spica in the constellation Virgo, which showed that it also had a dark companion, but so situated with regard to us that it never passed in front of the bright star. The observed peculiarity consisted in the dark lines of the spectrum of the star becoming slightly shifted towards the red and the blue end of the spectrum alternately, a fact which could only be explained by the revolution of the star in a short period, so that it would be alternately moving towards us or away from us, thus causing the observed displacement; while the fact that only one spectrum was seen showed that the companion star was, as in the case of Algol, invisible. In this case the plane of the star's orbit must be nearly in the direction of the earth but so much tilted out of the direct line that the dark star does not cause any obscuration of the bright one.

While these discoveries were being made in Europe the American astronomers were also engaged in obtaining numerous photographs of star-spectra, in some cases observing the same star night after night for a considerable time; and the examination of these photographs by Miss A. C. Maury in 1889 led to the interesting discovery that the dark lines of the spectrum were sometimes single and

sometimes double. The change was found to take place gradually, and in the case of the middle star in the tail of the Great Bear (Mizar), in which the phenomenon was first detected, the doubling occurred very regularly at intervals of fifty-two days. This led to the close examination of other series of photographs of star-spectra, and a number of other cases of periodical doubling of the lines were observed. In the case of the second brightest star in Auriga the period was only two days. In almost all these cases the star appears single in the most powerful telescopes, yet the spectroscope shows that it must really consist of two bright stars revolving round their common centre of gravity, the plane of the orbit being nearly in our direction. In one of these cases, however, that of Capella, the most powerful telescopes show a slight elongation, the direction of which changes from time to time, indicating, that the very close companion star detected by the spectroscope is almost visible, and will probably soon be completely separated in the very best telescopes now available.

We thus see that in three different ways the existence of what may well be termed invisible stars can now be detected. First, when, as in the case of Algol, a periodical obscuration of the light of the star occurs, and the spectroscope shows a change in the star's motion towards us or from us; secondly, when the spectroscope alone shows this change of motion indicated by a shifting of the dark lines of the spectrum to the red and violet ends of the spectrum alternately; and, thirdly, when some of the dark lines become double and again single at definite intervals, proving the existence of two luminous stars so close together that they appear as one in the most powerful telescopes.

In all these cases it must be noted that the planes of revolution of the pairs of stars must be either exactly or

nearly directed towards us, since when the plane is nearly at right-angles to our line of sight there will be no perceptible difference in the velocity of the apparent motion as regards us. But as the planes of revolution of double stars are probably in all directions, there must be a very large proportion that we can never detect by either of the methods now in use.

In some of the double stars, the path of which can be accurately mapped out, there are found to be certain irregularities in the orbit which appear to indicate another invisible star also revolving about the common centre of gravity of the three and causing perturbations in their orbits. We have here, therefore, another method of detecting the existence of invisible stars, a method which was successfully applied in the case of the companion of Sirius.

Some of the stars discovered by the spectroscope are wonderfully close together. In Beta Aurigæ the two stars are nearly equal in size, and revolve in four days, the actual distance between them being about 8,000,000 miles. The parallax of this star has been measured, and it can, therefore, be calculated that the angular distance of the component star is about $\frac{1}{200}$ of a second, an amount too small to be detected by the most powerful telescopes. As each of these close stars has a mass two and a half times greater than that of our sun, and as they are, presumably, also much larger, the distance between their surfaces can hardly be greater than their diameters.

The bright star Spica, in the constellation Virgo, which, as already stated, has been shown to be double by the same means, also revolves in about four days, the distance between its components being about $6\frac{1}{4}$ millions of miles, and the mass of the system about 2.6 times the mass of our sun. The parallax of this star has not yet been measured.

The closeness of these stars to each other, and the extremely rapid motions of such gigantic bodies, must lead to disturbances of which we can form no conception. It is now believed that these tidal disturbances, as in the case of our moon, lead to the separation rather than to the coalescence of the two bodies.

Other spectroscopic doubles are much farther apart. Mizar, in the Great Bear, is a double star easily visible, but one of its components is a spectroscopic double, already referred to, with a period of one hundred and four days and a distance apart of 143,000,000 miles. This star has a very small parallax, and its distance is so great that the component stars are less than $\frac{1}{20}$ of a second apart, and, therefore, invisible in any telescope.

Star-clusters

This term is usually applied to those groups of stars which appear as small stars or cloudy patches to the naked eye or a small telescope, but which, when viewed with higher powers, are seen to be condensed masses of stars often approximately globular in form, and packed so closely towards the centre as to appear like a nebulous mass, but which, with still higher powers, are seen to be formed of distinct stars. Ever since the discovery of the telescope these have been favourite objects with astronomers, but it is only since the application of the spectroscope to the heavens that they have been differentiated from nebulæ and some idea of their real nature attained. As their spectra are not gaseous but of the same type as most stars, they are evidently real clusters of stars or suns, and their apparent closeness towards the centre of the mass must be due either to a real closeness of small stars or to their enormous distance from us causing them to appear close.

The actual distance of any cluster has not yet been measured, because they are usually of such extent that stars not belonging to the cluster are too far off to furnish fixed points from which to determine their motions. In time this may be done by means of photography, if photographic plates of clusters are taken regularly at six months intervals, so as to show if any annual displacement with regard to other stars occurs. From general considerations of visibility and apparent closeness of the constituent stars, Mr J. E. Gore concludes that the fine cluster in Hercules, which consists of between 2000 and 3000 stars, may have a diameter of about 15,000 times the sun's distance from the earth, while the component stars are perhaps about 800 times that distance from each other. The distance of this cluster is probably so great that our sun, viewed from it, would become a star of about the tenth magnitude.

But the very small distance apart of many of the spectroscopic double stars—often far less than that of the sun from the earth—seems to render it possible that in these vast clusters of stars the distance apart may also be far less than that above referred to, and that they are really comparatively small individually and in process of aggregation into larger suns. Even if collisions are now occurring, they may not be frequent enough to be detected; while among the light of a thousand stars the spectroscope could hardly detect the gaseous spectra produced by the collision of one or two pairs. By the persistent use of the photographic method the astronomers of another century may be able to determine whether the component stars in these clusters are becoming denser towards the centre, while the spectroscope may indicate the physical results of such condensation.

Physics and Chemistry of the Stars

So far we have been occupied with discoveries in what may be termed the mechanics of the stars—their distribution, their numbers, their distances from us, their grouping in pairs and clusters, their visibility or invisibility, their relative brightness, their variability, their motions apparent and real, and their actual velocities in miles per second—on all of which details a flood of new information has been obtained, very largely by the aid of the spectroscope and of photography. But there yet remains an equally extensive and even more difficult field of research, which deals with the physical condition and chemical constitution of stars, and of which a still briefer outline is all that can be here attempted.

The colour of the light given out by a heated body varies with its temperature, as in the well-known case of hot iron becoming first dull red, and with greater heat a brighter red or yellowish, and then white. Kirchhoff showed that the hotter a body is the farther its spectrum extends towards and beyond the violet end of the solar spectrum. Therefore the bluish-white stars, the yellow-red, and the blood-red stars, indicate a series of decreasing temperatures.

The density of the gaseous envelope of stars is also indicated by the spectroscope, since it is found that under high atmospheric pressure in the laboratory the spectral lines of many of the elements are shifted towards the red end of the spectrum.

Magnetism also changes the appearance of the spectral lines, which often become divided into two or three separate lines in a powerful magnetic field. Both these changes are observed in certain stars, introducing great complexity in the phenomena, but also giving important information

as to the physical conditions prevailing in these remote bodies.

The chemical constitution of the stars as indicated by the spectroscope varies much, and is largely influenced by their temperature. The hottest stars have usually gaseous spectra, their peculiar lines indicating a form of hydrogen and some of the gases which exist only in the rare mineral "cleveite." At a slightly lower temperature metallic elements appear, and to this class our sun belongs. Other stars have much lower temperatures, and these have usually fluted spectra. (*See* Chapter X. Fig. 73, p. 203.) The stars of the lowest temperatures are believed to approximate to that of the electric arc, while the highest surpass that of the most powerful electric spark yet produced.

We have seen that the proper motions of the stars serve to indicate generally their distance from us. It is an interesting fact that those stars which most resemble our sun in temperature and in showing the lines of numerous metallic elements in their spectra, have large proper motions. Hence Sir Norman Lockyer concludes that they form, with our sun, a star-cluster, and that they are all approximately in the same phase of development. They are scattered all over the sky, which again they would be if they formed a cluster and we were somewhere near the centre of it. By a recent examination of all the stars having large proper motions Professor S. Newcomb has arrived at the same conclusion, as will be seen in our next chapter. The hottest stars of all, characterised by their bright-line spectra, lie mostly along the central line of the Milky Way, outside of which none are found; and these hottest stars have apparently the smallest number of chemical elements in their spectra, though, of course, this does not imply that other elements do not exist. Their

Fig. 93.—The Great Nebula in Orion
(Visible to the naked eye, and a very beautiful object when observed with a small telescope or opera-glass)

intense heat may drive off the lighter gases to form an outer envelope which alone may be seen by us.

Nebulæ

Of all the varied objects the heavens present to the astronomer's scrutiny, the most mysterious, the most varied, and at the present day the most instructive, are those vast irregular cloudy specks or masses termed nebulæ. Sir William Herschel, who first systematically examined the nebulæ with a powerful telescope, considered them to be really star-clusters so vast and so far distant that his highest powers could not resolve them, and the fact that numerous minute stars are often found in nebulæ, when the most powerful telescopes are used, seemed to confirm this view, which was not abandoned till the spectroscope showed that many of them consisted of luminous gases, among which hydrogen was most abundant.

The magnificent nebula of Orion, which can be well seen even with a good opera-glass, was the first nebula proved to be gaseous, by Sir William Huggins in 1864. The accompanying beautiful photograph (Fig. 93) by Dr Common shows the character of this wonderful body with extreme delicacy.

One of the most mysteriously irregular nebulæ known is that in the southern constellation Argus, which was carefully drawn by Sir John Herschel when at the Cape of Good Hope. This has been called the key-hole nebula, from the strange opening in its upper part, which is, however, only the most pronounced example of a feature of the whole body—its sharply defined and strangely curved outlines. Somewhat similar is the Trifid Nebula in Sagittarius (Fig. 94). This consists of three masses of nebulous matter separated by dark lanes or rifts. Near the junction of the three rifts is a triple star. The spectrum of this nebula is said to show that it is not gaseous.

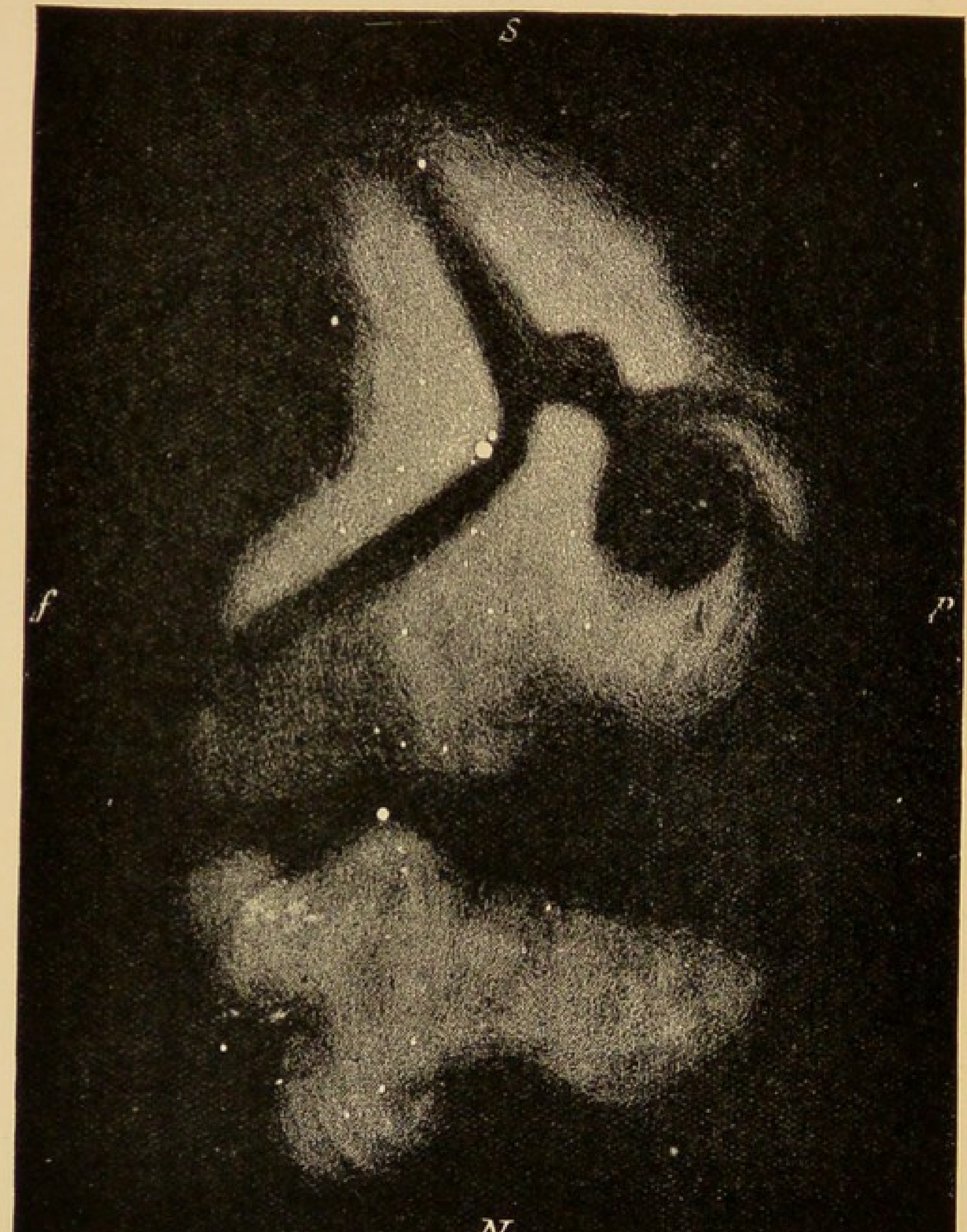


Fig. 94.—The Trifid Nebula in Sagittarius
From Flammarion's "Popular Astronomy," by permission of Messrs Hutchinson & Co.)

Another of the great and remarkable nebulæ is that in the constellation Andromeda often referred to as the great

spiral nebula. This also can be just seen with the naked eye as a hazy spot, and is a fine object in a good opera-glass. The photograph here reproduced (Fig. 95) shows that it extends in both directions far beyond the central white patch, its greatest extent being nearly four times the apparent diameter of the moon. Its elongated form no

Fig, 95.—Photograph of the Great Nebula in Andromeda

doubt arises from its being seen obliquely, it being really more or less circular in outline. It gives no sign of being resolvable into stars even by the most powerful telescopes, yet it does not exhibit the gaseous spectrum usual in nebulæ, but a continuous one like that of many of the star-clusters. It may, therefore, consist of an immense number of small stars, and, if partially gaseous, this may be in a

non-luminous condition. Another spiral nebula, "51 Messier," situated beyond the end of the tail of the Great Bear, has also a stellar spectrum, and the nucleus of the nebula is here visible as a nebulous star with another nucleus on an outer part of the spiral, while small stars are also seen in the body of the nebula.

There are a number of curious bodies which are termed planetary nebulæ from their having a more or less definite round disc like that of a planet, but very much fainter. Some of these are bluish in colour. The planetary nebula situated in the constellation Hydra now resembles Jupiter in its size, its equable light, and its colour, but Sir John Herschel found it more than sixty years ago to be decidedly blue, a colour rather prevalent in these objects. Most of the planetary nebulæ have gaseous spectra, but some are stellar. Several have minute stars in the centre; others are dotted with stars; others seem to form a ring or rings; while others again have a quite smooth uniform surface.

What is the nature of these strange bodies it is difficult to imagine, since they differ so widely from the vast irregular shapeless masses of other nebulæ, while their size is enormous. We may perhaps conjecture that they constitute an intermediate stage between irregular nebulæ and nebulous stars, which are themselves on the way to become true stars. From various considerations it has been estimated that the density of nebulæ is excessively small, far less probably than that of the tails of comets, and that they are only visible to us on account of their enormous bulk—many times larger than a globe which would contain the whole solar system. The late Mr Ranyard estimated the Orion nebula as being less than one-ten-thousand-millionth of the density of our atmosphere. With such excessive tenuity they might condense very slowly, forming first, by local condensations, a star-cluster, and ultimately

a star, their visibility being partly due to reflected light from the nearest stars, partly to innumerable slight collisions during condensation, sufficient to heat some of the more

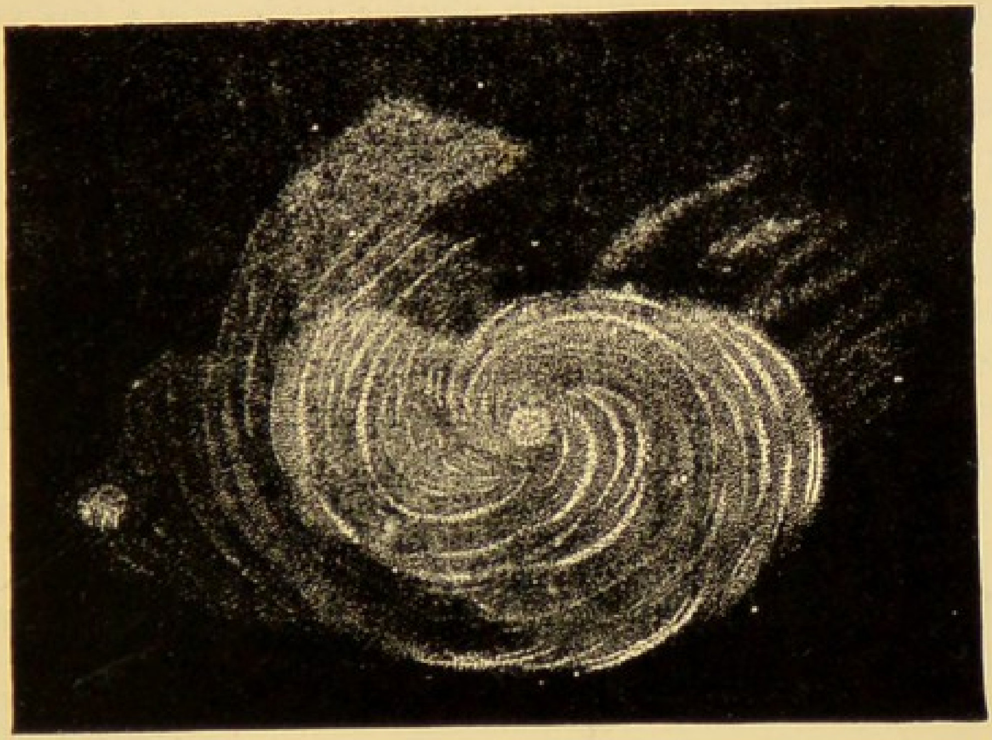


Fig. 96.—Spiral Nebula in Canes Venatici, "51 Messier"

permanent gases to incandescence, and thus faintly to illuminate the solid particles.

Concluding Remarks on the Advance of Star-Knowledge

The very brief sketch now given of the advance in our knowledge of the starry universe during the nineteenth century will serve to show how marvellous it is both in its nature and its results. And this is the more remarkable when we consider that in the early part of the century a great teacher of science and sociology—Auguste Comte—declared that all study of the stars, beyond that needed for fixing their positions in order to serve as data for determin-

ing the motions of the planets, was time wasted, since their enormous distance from us rendered it *impossible* for us ever to learn anything definite about their real nature and origin. Yet now, by discoveries in physics made only a few years after this was written, it may be truly said that we have obtained more detailed knowledge of the chemical and physical constitution of the stars and of their motions and of their relations to each other than we have of most of the planets. Instead of being the least fruitful domain of astronomy, the study of the remotest depths of the stellar universe has not only been the most productive in increased knowledge of a nature quite unexpected, but it has led to the use of so many new methods of research, and has opened up such vast possibilities, that we may still look forward to an indefinite advance of our knowledge in directions which, to our forefathers, appeared the most sterile and unpromising.

CHAPTER XV

THE STRUCTURE OF THE HEAVENS

> "From what beginning, what fire-fountain hurled,
> Burst the bright streams, and every spark a world."
>
> F. W. H. MYERS.

> "Far beyond Orion bright
> Cloud on cloud the star-haze lies;
> Million years bear down the light
> Earthward from those ghost-like eyes."
>
> F. T. PALGRAVE.

THE result of the modern study of the stars, their distances, their real magnitudes, their motions in space, their union in pairs, groups, and clusters, their variability, their chemical and physical constitution as indicated by their spectra, and their association with and relation to the strange and mysterious nebulæ—all these vast fields of research, as sketched in the barest outline in the preceding chapter, do not by any means comprise the whole of the New Astronomy. The still vaster problems of determining the total number of the visible stars, of their actual distribution in space, of the position which our system occupies in regard to them, and of the law of development which seems to govern the whole stellar universe, have all attracted the attention of the more advanced thinkers; and their conclusions, founded as they are upon a most extensive and laborious examination of the facts, are often of the greatest interest and well worthy of our careful consideration.

The Milky Way or Galaxy

By far the most prominent feature of the starry heavens is that vast irregular nebulous ring which in all ages has attracted the attention and excited the admiration of observers. Its plane lies at an angle of about 63° with the equinoctial, and its breadth is very variable, but it is narrowest where it approaches nearest to the north and south poles. In its course it divides into two portions, which join again, and it varies greatly both in general brightness and in its detailed structure and markings.

Although this great belt has to the eye the cloudy appearance of a nebula, yet this is believed to be wholly due to the aggregation of its component stars. As it is examined with higher and higher powers the number of stars increases; and when photographs are taken with a long exposure the numbers are again increased, so that there is every reason to believe that this vast luminous ring really exhibits to us the entire visible universe situated beyond that portion of which our sun forms a part. In detail, however, it presents many peculiarites, indicating what may be termed structure, in patches, streaks, and winding trains of stars interspersed with spots and patches of intense blackness, which, however, show everywhere a few minute stars sprinkled over them. The plate here given is a reproduction of a photograph of part of the Milky Way by Professor Barnard.

Sir John Herschel in his "Outlines of Astronomy" says: "When examined with powerful telescopes the constitution of this wonderful zone is found to be no less various than its aspect to the eye is irregular. In some regions the stars of which it is wholly composed are scattered with remarkable uniformity over immense tracts, while in others the irregularity of their distribution is quite

Fig. 97.—Portion of The Milky Way. From Photograph by Prof. Barnard
(By permission of The Royal Astronomical Society)

as striking, exhibiting a rapid succession of closely clustering rich patches separated by comparatively poor intervals, and, indeed, in some instances, by spaces absolutely dark and completely void of any star, even of the smallest telescopic magnitude. . . . In some, for instance, extremely minute stars, though never altogether wanting, occur in numbers so moderate as to lead us irresistibly to the conclusion that, in those regions, we see *fairly through* the starry stratum, since it is impossible otherwise, supposing their light not intercepted, that the members of the smaller magnitudes should not go on increasing indefinitely. In such cases, moveover, the ground of the heavens, as seen between the stars, is for the most part perfectly dark, which again would not be the case if innumerable multitudes of stars, too minute to be individually discernible, existed beyond."

These conclusions have now been confirmed by the largest modern telescopes, as well as by the still greater power of the photographic plate. Sir John Herschel, by the system of star-gauging over the whole heavens, found that the number of stars distinctly visible in his telescope increased regularly as they approached the Milky Way. This is strikingly illustrated by the following table in his "Outlines of Astronomy":—

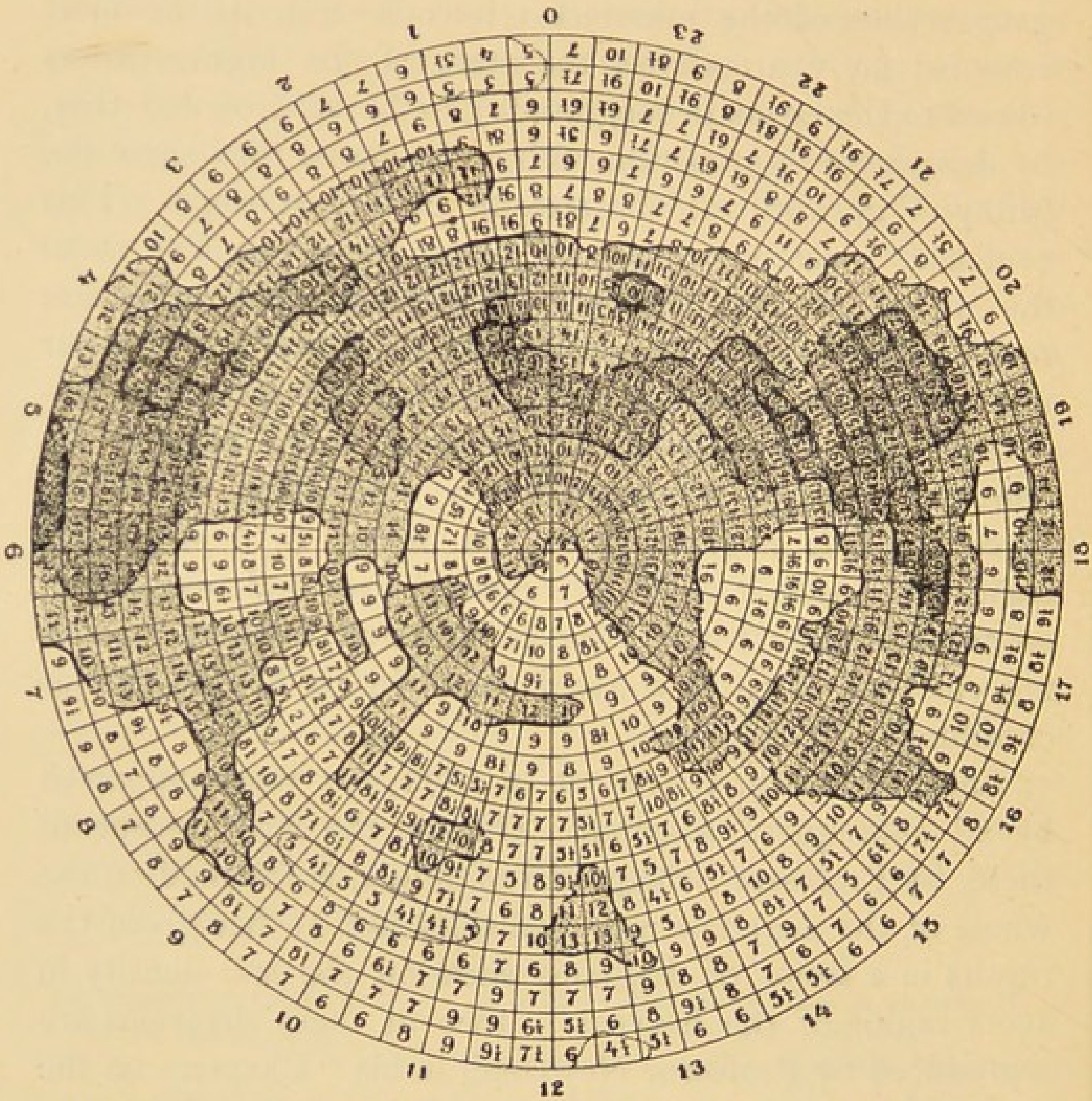
Distance from the Pole of the Milky Way	Average number of stars in an area of 15 feet square	
	Northern Hemisphere	Southern Hemisphere
0°—15°	4.32	6.05
15°—30°	5.42	6.62
30°—45°	8.21	9.08
45°—60°	13.61	13.49
60°—75°	24.09	26.69
75°—90°	53.43	59.06

The late Mr Proctor made an elaborate investigation of all

the stars catalogued down to the tenth magnitude, 324,198 in number, and these also showed a great increase of density towards the Milky Way. On this fact he remarks as follows:—"In the very regions where the Herschellian gauges showed the minutest telescopic stars to be most crowded my chart shows the stars of the higher orders (down to the eleventh magnitude) to be so crowded that, by their mere aggregation within the mass, they show the Milky Way with all its streams and clusterings. This evidence, I venture to affirm, is altogether decisive as to the main question, whether large and small stars are really intermixed in many regions of space, or whether the small stars are excessively remote. It is utterly impossible that excessively remote stars could seem to be clustered exactly where relatively near stars are richly spread. This might happen, no doubt, in a single instance; but that it could be repeated over and over again, so as to account for all the complicated features seen in my chart of 324,198 stars, I maintain to be utterly incredible."

This conclusion, arrived at in 1871, has been supported by all subsequent research. One of the most recent of these, by Professor Schiaparelli of Milan, is founded on the whole of the materials now available, and he has given the results in a series of diagrams showing the star-density in every region of the heavens. Two of these diagrams are reproduced by Professor Newcomb in his "Chapters on the Stars," and are given here by the kind permission of the publishers of *The Popular Science Monthly*. Professor Newcomb assures us that the Milky Way can be fairly traced out by the region of maximum agglomeration of stars, and that the central line of these denser regions only differs by about 5° from the central line of the galaxy itself (Figs. 97 and 98).

Another important piece of evidence as to the structure of the stellar universe is derived from the distribution of those stars which, having large proper motions, are almost certainly the nearest to us. It had long been noticed that



[Fig. 98.—Diagram of Star-Distribution in the Northern Hemisphere

the brightest stars are scattered irregularly over the heavens without any apparent relation to the Milky Way; but as it is now known that the brightest are by no means necessarily the nearest stars to us, the distribution of those with large proper motions is of much more importance.

The result of a careful examination of all these stars leads Professor S. Newcomb to the following result:—"If we should blot out from the sky all the stars having no proper motion large enough to be detected, we should find

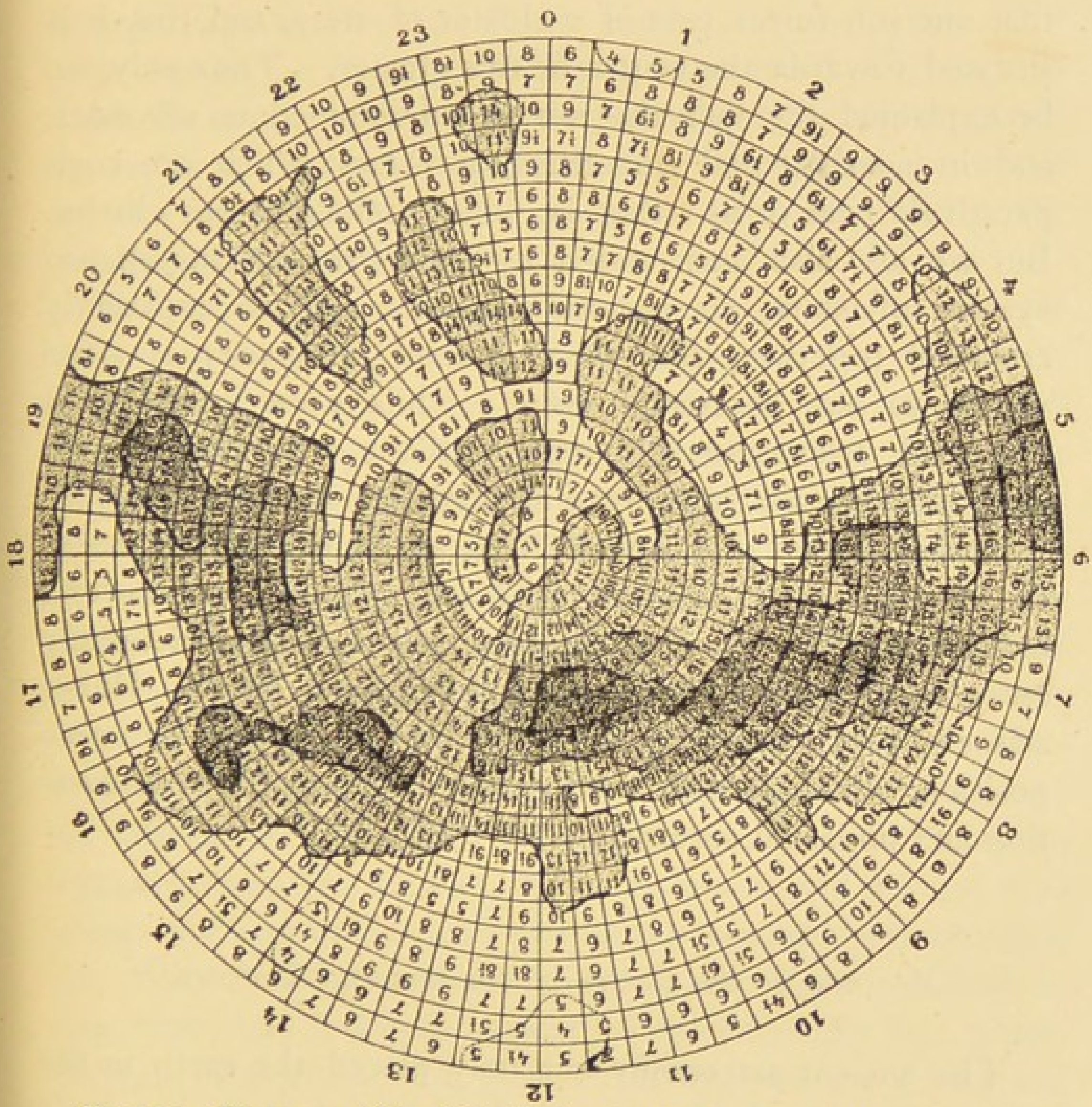


Fig. 99.—Diagram of Star-Distribution in the Southern Hemisphere

remaining stars of all magnitudes; but they would be scattered almost uniformly over the sky, and show no tendency towards the Milky Way."

The conclusion to be drawn from this fact is of the highest importance. It is, that we are surrounded on

every side by stars which are, comparatively speaking, at a moderate distance from us; while, on the other hand, the vast multitude of stars which constitutes the Milky Way itself is immensely more remote. It therefore appears that our sun forms part of a cluster of stars, and that it is situated towards the centre of this cluster. Thus only can be explained the fact that we are surrounded on all sides, and in nearly equal quantities, by stars which are comparatively near to us—that is, which belong to our cluster. But we are also surrounded by an enormous ring-shaped system of stars, so remote from us and so apparently crowded together, that their general luminosity is alone visible to our unassisted vision; while even in the most powerful telescopes, although millions are revealed, yet many still remain unresolved as luminous stellar clouds.

So far as we can penetrate into space, the galaxy marks the limit of the material universe. There are several independent proofs that it does not extend indefinitely away from us, but has fairly well-defined limits. Hence arises a very interesting consideration as regards our own position, which is well worthy our most careful consideration and impartial scrutiny.

Are we in the Centre of the material Universe?

The ancient astronomy not only placed the earth in the centre of sun and planets and the hosts of stars, but made it their ruler and centre of motion. The newer astronomy of Copernicus and Galileo gave us a subordinate position on one of the smaller planets revolving around one out of millions of suns. But the new astronomy of the latter half of the nineteenth century seems to indicate that we do really hold a position more truly in the centre of the

universe than was even imagined of old. For the supposition that best explains the various facts of stellar distribution as now known, is, that our sun is one of a considerable cluster of stars, and that it is situated *near to*, and perhaps *at*, *the centre of that cluster*. And, further, that this cluster, be it large or small, is situated not very far from the centre of that vast ring of stars which constitutes, so far as we know, or are ever likely to know, the whole of the material universe. Let us consider briefly the evidence on which this conclusion rests.

In the first place, as regards our position near the centre of our star-cluster, this follows from the fact stated by Professor Newcomb that the whole of the stars with measurable proper motions are scattered over the entire heavens with a general uniformity although with much irregularity in details. This could not be the case if we were situated much nearer to one side of our cluster than to the other, for in that case one-half of the heavens would present to us a much larger number of those nearer stars than the opposite half, and no such inequality of distribution can be observed. And as to the position of our cluster in relation to the Milky Way, if we were placed in an excentric position with regard to it, we should not see it as a vast and somewhat irregular ring completely surrounding us, and neither denser nor broader on one side of us than on the other, but it would appear to be decidedly less dense, though broader, on the side which was nearest to us, and more dense, though narrower, on the opposite side; but no such inequality in exactly opposite directions is found to exist. Again, as regards the plane of the ring, if we were situated at any considerable distance outside that plane the galaxy could not appear as a great circle, nor could any two opposite portions of it be 180° apart. But Sir John Herschel states that its course conforms as nearly as may

be to that of a great circle inclined about 63° to the equinoctial, and that it cuts that circle in Right Ascension 6h. 47m. and 18h. 47m. It thus appears that these points are exactly 180° apart to one minute of time, while its poles are given as in N. Decl. 27° and S. Decl. 27°—so that it is almost impossible for such an irregular object to more nearly conform to a great circle *from our point of view*.

It is singular that hardly any writers have commented on the very remarkable fact of our being situated so exactly in the plane of this marvellous ring of stars constituting, as it is now believed to do, the whole visible universe. And when we find that we are not only so exactly in its plane, but also very nearly at the central point of that plane, the coincidence becomes too remarkable to be due to chance alone, and we are almost driven to the conclusion that this central position has a purpose and a meaning. But there is more evidence of a very remarkable nature pointing in the same direction.

Our Position in the Solar System

When we come to examine closely our position in the solar system itself, with special regard to the conditions required for the development of high forms of life, we shall see that it is equally remarkable with that of our sun among the stars.

The first fact of importance to be considered is that all the planets, and even all stars and systems, are built up of the very same elements as those we find in our globe, so that we are not justified in calling to our aid new forms of matter and unknown physical and chemical laws in other parts of the universe. We have next to consider the essential characteristics of the structure of organised

beings which are, the continuous growth and repair of all the tissues by the absorption and transformation of organised or mineral substances into the various unstable compounds of which they are built up. This transformation and nutrition are carried on by means of a wonderfully complex double system of circulation, gaseous and liquid perpetually in operation, and carried on by means of minute tubular vessels which permeate every part of the body. In order that these circulating systems may be continuously in operation, a very uniform temperature, with a very limited maximum and minimum, is absolutely essential. Roughly speaking, the limits of temperature are about from 0° C. to 70° C., a very narrow range as compared with the temperatures of space—273° C., and that of boiling water—100° C. Yet it is absolutely essential that these narrow limits should have been maintained over a considerable portion of the surface of an inhabited planet for the enormously long periods required for the development of a system of organic life culminating in man—a period of probably tens or even hundreds of millions of years. In order to understand how complex and delicate are the adjustments which maintain the required uniformity of temperature and other meteorological conditions upon the earth, it will be well to enumerate them.

(1) A distance from the sun such as to allow the soil to be kept at a suitable warmth independent of internal heat, and also to cause the evaporation of sufficient water to produce clouds, rain, and a system of river-circulation.

(2) An atmosphere of sufficient depth to aid in the production and circulation of aqueous vapour in the form of clouds, mists, and dews, and to serve also as an equaliser of temperature during day and night, summer and winter, and between the tropics and the temperate zones. The amount of atmosphere is largely dependent

on the mass of the planet, and this one condition almost certainly renders Mars unsuitable, since its mass is less than one-eighth that of the earth.

(3) The large proportion of the surface covered by the oceans, surrounding and penetrating the land masses, and by means of their tides and currents acting as powerful agents in the equalisation of temperatures. This again is partly dependent upon our possessing a satellite capable of producing regular but not excessive tidal action; and the want of such a satellite may render Venus unsuited to be the theatre of life even if other conditions were favourable, which seems very improbable.

(4) Even more important is the great average depth of these oceans, and the fact that they are thirteen times the bulk of the land which rises above them, indicating that they are permanent features of the earth's surface, and have helped to maintain the unbroken continuity of terrestrial life. It is extremely improbable that this remarkable condition obtains in any other planet. (The evidence for the permanence of ocean basins is given in my "Island Life," with additional arguments in my "Studies Scientific and Social.")

(5) A little-considered phenomenon, but one that seems also essential to the development and maintenance of a high terrestial life, is an uninterrupted supply of atmospheric dust, which is essential to the production of rain-clouds and mists, and also of diffused daylight and other important phenomena (as already described in Chapter IX.). Now, the two great sources of atmospheric dust, distributed with such wonderful uniformity through the whole atmosphere, are deserts and active volcanoes, and a due proportion of these as permanent features during the whole of the geological epochs is probably one of the essentials for the development of intelligent life. I believe this is the first

time that the great importance to man of these features, usually held to be useless blots on the face of nature, has been pointed out.

If we now consider that these fine conditions, most of which must have been dependent on a delicate balance of the forces concerned in the origin of our planet, appear to be absolutely essential for the development of the higher types of terrestrial life, we shall realise how peculiar and unique is our position in the solar system, since we know, with some approach to certainty, that they do not now co-exist in any planet, and we have still less reason to think that they could have maintained the complex, equable conditions required during millions of years. It appears to be proved, therefore, that our earth does really stand alone in the solar system in its special adaptation for the development of intelligent life.

But granting this, it may be asked how the position of our sun at or near the very centre of the stellar universe can affect that adaptation? Why should not any one of the millions of suns in other parts of space possess planets as well adapted as we are to develop high forms of organic life? We cannot, of course, answer these questions definitely; but there *are* reasons why the central position we occupy may be alone suitable. It is almost certain that electricity and all the other mysterious radiant forces of which we have so recently discovered the existence have played an important part in the origin and development of organised beings, and it is surely not an extravagant idea that the extraordinary way in which those cosmic forces have remained hidden from us may be due to that very central position which we are found to occupy in the whole universe of matter discoverable by us.

It may well be that these forces of the ether are more irregular and more violent in their effects upon matter in

what may be termed the outer chambers of that universe, and that they are only so nicely balanced, so uniform in their action, and so concealed from us, as to be fit to aid in the development of organic life in that very central portion of the stellar systems which we are found to occupy. Should these views as to the unique central position of our earth be supported by the results of further research, it will certainly rank as the most extraordinary and perhaps the most important of the many discoveries of the past century.*

The Distribution of Star-Clusters and Nebulæ

Having thus reached a definite conclusion as to the general form and structure of the great universe of stars, we may compare with them the other material objects which people the heavens. The result of the most careful inquiries shows that star-clusters agree in their distribution with individual stars—that is, they abound in the region of the Milky Way and diminish rapidly as we go away from it: and the same law applies to planetary nebulæ. And this is what we should naturally expect, because, we being ourselves situated in a star-cluster, there can hardly be definite clusters within it; and as stars themselves are very thinly scattered outside our cluster except in the region of the Milky Way, clusters of stars are hardly likely to be found elsewhere. As to planetary nebulæ, they are probably a form of cluster in which the components are very small—possibly globular masses of meteorites in process of formation into stars. Ordinary irregular nebulæ, however, have a quite different distribution, being really more numerous in other parts of the heavens than in or near the Milky Way. This would

* A fuller exposition of this subject will be found in the author's volume, "Man's Place in the Universe."

seem to show that they exist in the outer parts of our star-cluster, and that they may constitute the remnants, as it were, of the materials out of which the stars of our cluster were formed. When projected against the luminous field of the Milky Way they would be indistinguishable, and thus seem to be more abundant in all other directions.

The Number of the Stars

One more general question has to be answered, the possible or probable number of the stars. The materials for any accurate determination do not yet exist, but certain conclusions have been reached which are of considerable importance. The first point to determine is whether there is any evidence to show that the number of the stars and the extent of the stellar universe are or are not infinite; and there are found to be two distinct lines of argument against the supposition of infinity.

In the first place, there is an optical law which indicates clearly that if the stellar universe is unlimited it cannot continue to be as thickly occupied with light-giving stars as the regions around us. This law is very clearly set forth by Professor S. Newcomb. He asks us to suppose a series of concentric spheres each at the same distance apart from the first, which includes only the stars visible to the naked eye. The space between each pair of these spheres will be in extent proportional to the squares of the diameters of the spheres which limit it, and as the light we receive from each star is inversely proportional to its distance from us, it follows that if each of the regions were equally strewn with stars of the same average brightness, then each region would give us the same amount of

light. Hence it follows that if the regions were infinite in number, and light were not lost in passing through space, we should receive an infinite amount of light—at all events, quite as much light as the sun gives us at noonday. But the densely black tracts of sky everywhere found between the stars, and even in rifts and open spaces in the Milky Way itself, are quite against any approach to such a state of things.

The other consideration leading to the same result is derived from a study of the number of stars in any limited region and the additions made by successively increased powers of the telescope. For a time each increase of telescopic power and light adds very greatly to the number of visible stars, but after a time any further increase in the size of the telescope adds but little, and there seems to be a limit to the numbers actually existing there. The same thing occurs with the photographic plate. When this is exposed in the focus of a telescope for three hours a much greater number of stars is seen than any eye can detect with the same telescope; but a longer exposure beyond the three hours adds but little to the number, indicating that the limit of stars in that direction is nearly reached.

The same thing is implied by a count of the stars of lower magnitudes. At each lesser magnitude the number of stars is about three times that of the next higher magnitude, and this rule applies with tolerable accuracy down to the ninth. The total number of visible stars from the first to the ninth magnitude is estimated to be about 200,000. Now, if this rate of increase continued, the numbers down to the seventeenth magnitude—the faintest stars visible in the most powerful telescope—would be nearly 1,400,000,000. But both telescopic observation and photographic charts show that there is nothing

approaching this number, it being estimated that the total number thus visible does not exceed 100,000,000.

It thus appears, from several independent lines of evidence, not only that the stellar universe which we see around us is not of infinite extent, but that we can already, almost if not quite, see to its outer limits. To have reached such a conclusion, not from imagination or theory, but as the result of the direct observation of great masses of facts and phenomena, must be considered a very remarkable triumph of the human intellect.

We will now consider the chief attempts to explain the development of the existing universe from some immediately preceding simpler condition.

The Nebular Hypothesis

This celebrated speculation was originated by the great mathematician Laplace, in 1796, and somewhat modified in later editions of his great work on "The System of the World," but it was put forth only as a "speculation" not supported by any detailed numerical or mathematical examination. It has, however, been generally adopted by astronomers, and the great reputation of its author has led to its being taken for granted that it was mathematically unassailable, while it has been extended from the solar system, to which alone Laplace applied it, to the whole stellar universe, so that it becomes necessary to review its applicability to our present state of knowledge so far beyond anything that Laplace dreamed of.

This theory supposes that the solar system began its existence as a vast glowing mass of gases extending beyond the orbit of the remotest planet, and consisting of the whole of the matter in the sun and planets changed by heat into the gaseous condition, and having a slow rotatory motion.

Such a vast mass as it cooled would contract in bulk, and, under the law of gravitation, the outer portions would slowly fall towards the centre, and in doing so the rate of rotation would increase. At length the rate of rotation of the outer portion would become so great that the centrifugal force would first balance the force of gravity and then become greater, so that a ring of nebulous matter would be left behind. This ring, owing to slight inequalities in its form and density, would break into fragments, which, being attracted towards the largest masses, would coalesce into a planet which would go on revolving about the central mass at the same distance as that of the original ring.

At successive epochs of contraction other rings would be left behind, forming the planets which now circulate around our sun, and a similar process during the cooling and contraction of the planets would produce the various systems of satellites. This theory of the formation of the solar system was thought by Laplace to be strongly supported by the rings of Saturn, which he supposed to be portions of the Saturnian nebula not yet condensed into a satellite.

It is rather an extraordinary illustration of the influence of a great reputation that this theory should not only have been almost universally accepted by astronomers during the first half of the nineteenth century but that it should have been extended so as to include the whole stellar universe, and even at the present day be constantly referred to as if, instead of being an ingenious speculation, it were a demonstrable inference from the theory of gravitation.

But, during the last forty years, many eminent men have shown that it is full of difficulties, and that much of it depends upon assumptions that are now known to be erroneous. It was, for instance, supposed to explain the fact

of the planets and their satellites all rotating and revolving in one direction, but it is now known that both Uranus and Neptune rotate on their axes and their satellites revolve round them in a direction opposite to that of all the other planets and their satellites.

Again, Laplace supposed that the solar nebula was wholly gaseous and continuous, and that the outer portions revolved in the same *time*, and therefore at a more rapid *rate* than the inner parts, just as our atmosphere at many miles elevation revolves in the same time as that on the sea-level, and therefore more rapidly owing to its greater distance from the centre. This is, of course, due to its viscosity, the friction of the adjacent portions of liquids and gases causing them to behave in this respect as if they were solids. But we now know that the supposed analogy of Saturn's rings completely fails, since it has been proved that they consist of solid particles, each moving in an independent orbit around the planet, the outer portions moving much less rapidly than the inner. It is also urged that even if the solar nebulæ were once a continuous gas of almost unimaginable tenuity, the process of throwing off portions by centrifugal force would not act at long intervals, so as to throw off complete rings, but continuously, leaving behind it small fragments of matter which might cool into meteoric dust, but would have no tendency to aggregate into planets. So obscure is the whole process that the most eminent mathematical astronomers are not yet agreed as to the comparative age of the planets, some holding that those nearest the sun were the first formed, others that all originated about the same period, while the essence of Laplace's theory is that they were thrown off successively during the contraction of the nebula, and that the outer ones are by far the oldest and those nearest to the sun the youngest. The numerous spiral nebulæ in the heavens are often adduced

as showing an analogous state of things to that supposed by Laplace, and to support his theory. But although many nebulæ exhibit a gaseous spectrum in which hydrogen predominates, yet the greater number, and also some of the best defined spiral nebulæ exhibit stellar spectra, showing that they consist largely of luminous solid matter. Even those that are apparently gaseous may not be wholly so, since their solid portions may not be so heated as to be luminous; and this is rendered more probable by the fact that the only gas certainly detected in them is hydrogen, the element which can exist in the gaseous form at the lowest temperature, and which may, therefore, persist in the stellar spaces long after all other forms of matter, even if once gaseous, have become solid by loss of heat. And this brings us to a fundamental objection to the nebular hypothesis as formulated by Laplace and as generally accepted by those who use the term at the present day, which, so far as I am aware, has not been stated by any of the critics of that theory, and which yet seems to me to be the strongest of all the objections to it. As a non-mathematician I therefore state it with some hesitation.

Laplace's Nebular Hypothesis assumes a physically unstable primitive Condition of the Solar System

If there is one point more clear and more generally accepted than another, it is that the matter of the sun and planets is practically identical—that is, all consist of the same elements; and this conclusion applies with almost equal probability to the vast number of bodies in the stellar universe. It is evident, therefore, that the primitive solar nebula of Laplace must have contained all the known elements in a gaseous condition, and that this condition

must have persisted during the whole process of contraction till the last planetary ring was thrown off. But in order to realise what would take place we have to consider, the condition as regards density of the outer portions of the solar nebula; and, the temperature needed to keep the whole of the elements in the gaseous state.

(1) *Density of the Solar Nebula.*—Few writers that I am acquainted with have dwelt upon the very small amount of matter in the solar system in proportion to its extent and *in relation to the nebular hypothesis.* The sun is so large that, although its density is only one-fourth that of the earth, the amount of matter in the whole of the planets is a very small fraction of it. But the distance of the planet Neptune is so vast that the diameter of its orbit is more than six thousand times the diameter of the sun. If, therefore, the primitive solar nebula was roughly globular and extended no farther than the orbit of Neptune, which is very improbable, its matter would have filled a space 216 thousand million times that which it now occupies. Even if it were uniformly spread throughout this vast space, the gases composing it would be about one two-hundred-millionth of the density of our air. But at about one-millionth of an atmosphere air begins to lose some of its properties in consequence of the rarity of collisions among its molecules. These are the kind of vacua in the well-known radiometer bulbs, and when higher vacua are used the motion of the vanes of the instrument becomes less pronounced or ceases altogether. It is certain, however, that in a mass of gas of the dimensions here postulated, the outer portions would be hundreds, perhaps thousands or even millions of times less than the mean density, so that the region in which the Neptunian ring is supposed to have been thrown off would have been occupied by gaseous matter of the inconceivable tenuity of the thousand-millionth of an atmos-

phere or, perhaps, even a still nearer approach to an absolute vacuum!

That any gas in this state of tenuity could behave in the manner required by Laplace's hypothesis is quite inconceivable; but when we consider that this outer portion of the solar nebula is supposed to have contained most of the elements in a gaseous state, a state which could not be maintained at all unless they were subjected to a heat as high as that of the electric arc, the difficulty becomes so much greater as to be absolutely unthinkable. For we know that the temperature of stellar space is so low that even hydrogen could only exist as a liquid or a solid, while every other known gas becomes solid at far higher temperatures. Even if we suppose any such catastrophe as would have raised the whole mass of the sun to a temperature not only sufficient to turn all its substance into gases, but also to superheat them to such an extent that they would expand so as to occupy the vast space extending to the orbit of Neptune, we must ask ourselves, How long would gaseous iron and carbon, aluminium and silica remain in that state when so rarefied that their molecules were far apart and exposed, in one direction at all events, to a temperature below that of liquid hydrogen? It seems physically certain that if any possible agency could have caused their molecules to be driven so far apart and to such remote depths of space, they could only reach it in the form of minutest solid dust. The whole conception, then, of a *gaseous* solar nebula extending beyond the orbit of Neptune is at once inconceivable as to origin and impossible as to more than a momentary existence. There are many other objections of equal weight, but it is unnecessary to give them here. Those who are interested in the question will find them clearly set forth by Miss A. Clerke, in *Knowledge*, of May 1903

The Testimony of Phenomena in the Solar System

When we inquire what evidence we have in the solar system itself in support of or adverse to the nebular hypothesis, we find that the analogies are all in favour of a solid rather than a gaseous state of matter in those phenomena that bear the most resemblance to the hypothetical solar nebula. The tails of comets and the zodiacal light both present us with visible matter in a state of almost inconceivable tenuity. The fact that a comet has passed through the sun's corona at a distance of only 100,000 miles from the sun's surface without being destroyed or apparently injured proves that neither of these bodies are gaseous, since if they were so the excessive velocity of the comet—366 miles a second—would have developed enormous friction and so much retardation of its motion that it must have fallen into the sun. The same thing is indicated by the fact that we have ourselves twice passed through a comet's tail without knowing it! Another comet passed among the satellites of Jupiter without in the least disturbing the motion or appearance of those bodies. The only tenable conclusion is that comets and their tails consist mainly of minute solid particles, a kind of cosmic dust, each particle, however small, pursuing its own course in the orbit round the sun, while the separate particles are so far apart that, unless disturbed by some external force, they never collide with one another. When approaching the sun, however, they are subject both to occasional collisions with some of the matter of the meteoric rings which abound in that region, and also to electrical repulsion, which, driving off the minuter particles, forms the tail, and produces more collisions, resulting in ignition of minute particles and the production of a small amount of hydro-carbon gases, both of which sources of light are indicated by the spectroscope,

The same kind of evidence shows that the outer appendages of the sun, the chromosphere and the zodiacal light, are not gaseous atmospheres, but solid particles continually thrown out from the sun, perhaps in a gaseous form at their origin, but instantly condensing into solid matter and then falling back to its surface. But if none of the matter of the sun can exist as a gaseous atmosphere, even at one-eighth of its diameter above its surface, how impossible it is to conceive that any such matter could retain the gaseous state through the vast planetary spaces. Yet the nebular hypothesis require that they should do so!

We see, then, that the solar system possesses apparently nebulous masses in comets and their tails and in the outer solar appendages, but that these invariably consist of minutely divided solid matter, as do the apparently nebulous rings of Saturn and the invisible meteoric rings of which comets are themselves a part; and there is nowhere any indication of gaseous matter except as a product of the collision of solid particles, and then only of such gases as can maintain the gaseous state at very low temperatures. The evidence afforded within the limits of the solar system is, therefore, wholly opposed to a nebular and wholly in accordance with a meteoritic theory of its origin.

(2) *The Meteoritic Hypothesis.*—On this theory nebulæ are supposed to be vast aggregations of meteorites or cosmic dust moving slowly in spirals, in ellipses, or in irregular streams, and so sparsely scattered that each dust-particle can move freely and rarely collide with any of its fellow-particles. The collisions and aggregations that do occur are sufficient to produce a slight luminosity, which, in masses many times larger than the whole solar system, becomes visible to us. Their temperature is very low, but sufficient to retain hydrogen and a few other elements in the gaseous state. As these masses slowly condense under

the influence of gravitation, they become hotter and more luminous, bringing them to the condition of nebulous stars, and further condensation would produce true stars of low temperature. From this point continuous condensation by gravitation would increase the temperature till a very hot star was formed and the maximum surface temperature reached. From this point the loss by radiation would for a time balance, and later exceed, the increase due to contraction, and the star would slowly cool till it became gradually less bright, then dull red, and ultimately invisible. All these stages have been traced by means of the spectroscope, and are fully described by Sir Norman Lockyer in his works on "The Meteoritic Hypothesis" and that on "Inorganic Evolution." The spectra of many stars show them to be clouds of incandescent stones, and there is an almost perfect transition from the most diffused nebulæ to the most brilliant stars.

The sudden appearance of "new stars," which sometimes attain great brilliancy and then fade away in a few days, weeks, or months, receive their only intelligible solution on the meteoritic theory. These occur most frequently in the region of the Milky Way, and are supposed by Sir Norman Lockyer to be due to the collision of two masses or streams of meteoric dust of great extent but of extreme sparseness. The quantity of matter and the size of the particles being very small, the heat and light produced by their collisions are soon lost by radiation into the cold spaces that surround them, and they thus fade away in a very short period into partial or total invisibility. In the new star which appeared a few years back in the constellation of the Charioteer—"Nova Aurigæ"—the spectrum showed bright and dark lines of hydrogen and calcium side by side, indicating that the light from these elements in an incandescent state passed through cooler

vapours of the same substances which by absorption produced the dark lines, while the distance apart of these identical lines indicated a differential motion of about 500 miles a second. This is interpreted as being due to the collision of two very sparse meteoritic swarms of nearly similar composition.

This doubling of the lines has occurred in the last four new stars, indicating motions towards and away from us of from 300 to 1000 miles a second. The most recent of these new stars—"Nova Persei"—which appeared in 1901, presented some peculiarities difficult to explain which are still engaging the attention of astronomers.

One of the chief Continental upholders of the meteoritic theory is the eminent Italian astronomer, Schiaparelli, who some twelve or fifteen years back stated his conclusions to be somewhat as follows:—

(1) Matter is disseminated throughout the celestial spaces from stars to comets and nebulæ or cosmical clouds, all consisting primarily of solid particles varying in size from microscopic dust upwards, and whose collisions produce heat and drive off gases.

(2) When any of these smaller nebulæ come within the attractive sphere of the solar system, they are liable to be drawn into it in a comparatively thin line or stream, and in a path round the sun which is either parabolic or elliptical; and if they happen to cross our orbit, whenever we pass that part of it some of them enter our atmosphere, are ignited by the resistance and friction, and produce the well-known showers of meteors or falling stars.

(3) These bodies are then real stars or suns on an infinitesimal scale, coming originally from outside the solar system, and consisting of the same materials as those which, when condensed in enormous masses, form the fixed stars.

(4) From those meteorites which occasionally fall upon

the earth in considerable masses we obtain samples of the matter which is scattered through the stellar spaces.

This conception of the meteoritic constitution of the whole stellar universe is one of the grandest achievements of the science of the nineteenth century. All the other astronomical discoveries of the period (except those gained through the spectroscope and by means of photography) are additions to our knowledge of essentially the same nature as others which preceded them; but in this case we have a new and comprehensive generalisation which links together a vast host of phenomena which, till quite recently, were isolated or misunderstood.

Beginning with the meteoric masses which at considerable intervals fall upon the earth, and the meteoric or cosmic dust which in minute spherules is probably always falling—since it is found abundantly in all the deepest oceanic deposits far removed from continental land—we have next the meteor streams with their attendant comets circling round the sun in vast numbers; the planetoids, ever increasing in recorded numbers and probably forming the larger members of a broad and extensive meteor ring; and the rings of Saturn, now proved to be of the same meteoritic nature. Then, passing on to the interstellar spaces, we find the nebulæ, which are but vast uncondensed meteor swarms, the planetary nebulæ and nebulous stars being examples of greater condensation, leading on to the myriads of the starry hosts, each one a sun heated by the inward rush and titanic collisions of countless meteor-swarms. These suns, after reaching a maximum of heat and light, slowly cool into darkness, until a collision with other cosmic matter again heats the mass to incandescence or even to vaporisation—all this grand series of phenomena, rising from dust-particles on the ocean bed to a hundred millions of suns, comprehended, and to some extent ex-

plained, by one of the simplest and, at first sight, most inadequate of hypotheses—that of a meteoritic origin of the material universe.

It has been objected that this theory is not so simple as the old nebular hypotheses, and has no advantages over it. But this is a mistake. The latter begins with what we now see to be an impossible condition—that of a universe in an excessively diffused gaseous state. For all matter, in the absence of heat, is solid, and the only sources of heat we know of are impact or friction and chemical combination, including electric action. Heat, therefore, in all its degrees and manifestations, will necessarily arise from diffused solid matter subject to gravitation, but it will arise partially and locally, not universally; and we now know that there *are* such varieties of temperature in the stellar universe. We have also positive evidence of solid matter everywhere, in an almost infinite gradation of size and of temperature, from that amount of cold in which no liquid, and perhaps no gas, can exist, up to that amount of heat in which all the elements are vaporised. We *can* conceive how, from diffused solid matter, without heat, the actual condition of the universe may have arisen, but we *cannot* conceive any previous condition which would result in the universal vaporisation of all matter which the nebular hypothesis presupposes.

The Vortex-Theory of Matter

But this grand meteoritic theory, like all possible theories or speculations as to the origin of the cosmos, only takes us one step backward, and then leaves us no whit nearer to a real comprehension of the great insoluble problem.

For we ask, Whence came this inconceivably vast extension of meteoric matter? What was its antecedent state? How did matter, at first presumably simple or atomic, aggregate into those forms we know as elements? And even if we could get back to a universe of primitive atoms we should still be no nearer a complete solution, for then would begin a new series of questions far more difficult to answer. We should begin to seek after the origin of the FORCES which caused the development of atoms into matter and into worlds. Whence the simplest cohesive forces? Whence the chemical forces? And, more mysterious than all, Whence the force of gravitation, infinite, unchangeable, and at the very root of cosmic development? Beyond these problems again, and quite as essential and insoluble, are the problems of the ether. What is the ether, and what are its relations to matter? Whence the forces that cause the ether to vibrate, and in the various forms of heat, light, or electricity to be the source of all change of form, all molecular motion, all those infinite modifications in the states of matter that alone seem to render possible the development of organised living beings? To all these questions we have no definite answers, and probably never shall have; but we have at least one suggestive speculation, that of the vortex-theory of matter.

According to this theory the ether is an incompressible, frictionless fluid, and is the one and only substance of the universe. Matter is but a form or mode of motion of the ether. Atoms are minute vortices, or rapidly revolving portions of the ether, which, when once started in this frictionless fluid, are eternal and indestructible. A sufficient number (almost infinite) of these vortices, of various dimensions and spinning with various velocities, and having progressive motions in every possible direction like the

molecules of a gas, will, it is suggested, group themselves into various aggregations according to similarities of size and motion; will thus produce the elements; which elements will act upon each other in the various modes of chemical combination: and thus will arise all the forms of molecular matter. But the continued motions of these atoms and their combinations will set up in the unmodified ether the special vibrations of heat and electricity which, reacting on matter, will lead to that vast series of co-ordinated changes we recognise as the laws and phenomena of nature. Whether gravitation could possibly arise from the initial impulse given to the ether is doubtful; but in this vortex-theory, of which Lord Kelvin is the chief exponent in this country, we have the most important attempt yet made to get near to the beginnings of the universe. It is, of course, essentially inconceivable, as are all fundamental conceptions. The incompressible, frictionless, universal fluid is inconceivable; the origin of its infinity of atomic vortex motions is inconceivable; as are the translatory motions, the infinity of combinations, the complexity of chemical actions, the production of the varied kinds of ether-vibrations, and of gravitative force; and when we have fully grasped all these inconceivabilities there remains the still greater inconceivability of how life, consciousness, affection, intellect, arose from this infinite clash of ethereal vortex-rings!

The conception is, however, a grand one; and, together with the meteoritic hypothesis as to the immediate antecedents of the visible universe, must rank among the great intellectual achievements of our century. Yet they bring us no nearer to the First Cause of this vast cosmos in which we live; and most minds will feel that we never can get nearer to it than in "the consciousness of an Inscrutable Power manifested to us through all pheno-

mena," which Herbert Spencer considers to be the logical and the utmost outcome of the most far-reaching human Science.*

"Is not every atom of dust, which compacted we call the earth,
A miracle baffling our thought with insoluble wonders of birth?
And know we not, indeed, that the matter which men have taught
Is itself an essence unseen and untouched but by spirit and thought?"
SIR L. MORRIS.

* Since this chapter was written, Professor Osborne Reynolds, F.R.S., has published his new theory of the nature of matter and ether. A popular account of this theory was the subject of the Rede Lecture in 1902, published under the title: "On an Inversion of Ideas as to the Structure of the Universe." It is very difficult to understand; but the great ability of the author, and his expressed conviction that "there is one, and only one, conceivable mechanical system capable of accounting for all the physical evidence, as we know it, in the universe," and that he has found and demonstrated that system, will certainly secure for it the attention it deserves and requires. He also claims that it is the only theory of the universe that explains gravitation.

CHAPTER XVI

GEOLOGY: THE GLACIAL EPOCH, AND THE ANTIQUITY OF MAN

> "The hills are shadows, and they flow
>   From form to form, and nothing stands;
>   They melt like mist, and solid lands,
> Like clouds they shape themselves and go."
>
> TENNYSON.

> "With cunning hand he shapes the flint,
>   He carves the bone with strange device,
> He splits the rebel rock by dint
>   Of effort—till one day there flies
> A spark of fire from out the stone,
> Fire, which shall make the world his own."
>
> MATHILDE BLIND.

THE foundations of modern geology were laid, in the latter part of the eighteenth century, by Werner, Hutton, and William Smith, but most of the details and some of the more important principles were wholly worked out during the nineteenth century. The great landmarks of its progress can alone be referred to here, namely (1) the establishment by Lyell of what has been termed the uniformitarian theory; (2) the proof of a recent glacial epoch and the tracing of its varied effects upon the earth's surface; and (3) the discovery that man in the northern hemisphere lived contemporaneously with many now extinct animals.

In the early part of the century, and so late as the year 1830, Cuvier's "Essay on the Theory of the Earth" held the field as the exponent of geological theory. A fifth edition of the English translation appeared in 1827, and a German

translation so late as 1830. In this work it was maintained that almost all geological phenomena pointed to a state of the earth and of natural forces very different from what now exists. In the raised beds of shells, in fractured rocks, in vertical stratification, we were said to have proofs "that the surface of the globe has been broken up by revolutions and catastrophes." The differences in the character of adjacent stratified deposits showed that there must have been various successive irruptions of the sea over the land; and Cuvier maintained that these irruptions and retreats of the sea were not slow or gradual, "but that most of the catastrophes which have occasioned them have been sudden." He urged that the sharp and bristling ridges and peaks of the primitive mountains "are indications of the violent manner in which they have been elevated"; and he concludes that "it is in vain we search among the powers which now act at the surface of the earth for causes sufficient to produce the revolutions and catastrophes, the traces of which are exhibited in its crust." This theory of convulsions and catastrophes held almost universal sway within the memory of persons now living, for although Hutton and Playfair had advanced far more accurate views, they appear to have made little impression, while the great authority attached to Cuvier's name carried all before it.

But in 1830, while Cuvier was at the height of his fame, and his book was still being translated into foreign languages, a hitherto unknown writer published the first volume of a work which struck at the very root of the catastrophic theory, and demonstrated, by a vast array of facts and the most cogent reasoning, that almost every portion of it was more or less imaginary and in opposition to the plainest teachings of nature. The victory was complete. From the date of the publication of the "Principles of Geology"

there were no more English editions of "The Theory of the Earth."

Lyell's method was that of a constant appeal to the processes of nature. Before asserting that certain results

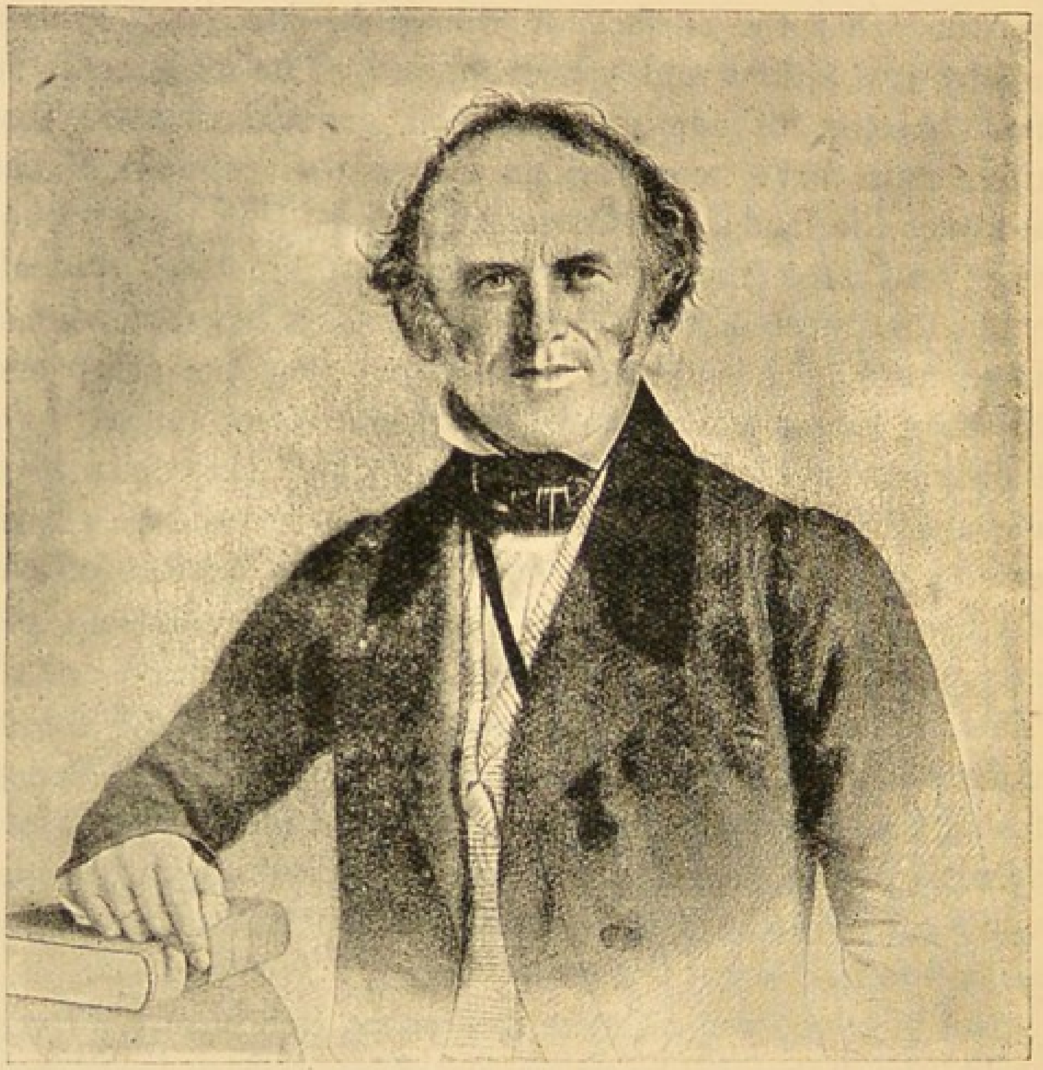


Fig. 100.—Sir Charles Lyell

could not be due to existing causes he carefully observed what those causes were now doing. He applied to them the tests of accurate measurement, and he showed that, taking into account the element of long-continued action, they were, in almost every case, fully adequate to explain

the observed phenomena. He showed that modern volcanoes had poured out equally vast masses of melted rock, which had covered equally large areas, with any ancient volcano; that strata were now forming, comparable in extent and thickness with any ancient strata; that organic remains were being preserved in them just as in the older formations; that land was almost everywhere either rising or sinking, as of old; that valleys were being excavated and mountains worn away; that earthquake shocks were producing faults in the rocks; that vegetation was now preparing future coal-beds; that limestones, sandstones, metamorphic and igneous rocks were still being formed; and that, given time, and the intermittent or continuous action of the causes we can now trace in operation, all the contortions and fractures of strata, all the ravines and precipices, and every other modification of the earth's crust supposed to imply the agency of sudden revolutions and violent catastrophes may be again and again produced.

During a period of more than forty years Sir Charles Lyell continued to enlarge and improve his work, bringing out eleven editions, the last of which was published three years before his death; and rarely has any scientific work so completely justified its title, since it remains to this day the best exposition of the "Principles of Geology"—the foundation on which the science itself must be and has been built. The disciples and followers of Lyell have been termed "Uniformitarians" on account of their belief that the causes which produced the phenomena manifested to us in the crust of the earth are essentially of the same nature as those acting now. And, as is often the case, the use of the term as a nickname has led to a misconception as to the views of those to whom it is applied. A few words on this point are therefore called for.

Modern objectors say that it is unphilosophical to main-

tain that in our little experience of a few hundred, or at most a few thousand, years, we can have witnessed all forms and degrees of the action of natural forces; that we have no right to take the historical period as a fair sample of all past geological ages; and that, as a mere matter of probability, we ought to expect to find proofs of greater earthquakes, more violent eruptions, more sudden upheavals, and more destructive floods having occurred during the vast eons of past time. Now this argument is perfectly sound if limited to the occurrence of extreme cases but not if applied to averages. No uniformitarian will deny the probability of there having been *some* greater convulsions in past geological ages than have ever been experienced during the historical period. But modern convulsionists do not confine themselves to this alone, but maintain that, *as a rule*, all the great natural forces tending to modify the surface of the earth were more powerful and acted on a larger scale than they do now. On the ground of mere probability, however, we have no right to assume a diminution rather than an increase of natural forces in recent times, unless there is some proof that these forces have diminished. Sir Charles Lyell shows that the cases adduced as indicating greater forces in the past are fallacious, and his doctrine is simply one of real as against imaginary forces.

But our modern objectors have another argument, founded upon the admitted fact that the earth has cooled and is slowly cooling, and was probably once in a molten condition. They urge that in early geological times, when the earth was hotter, the igneous, aqueous, and aërial forces were necessarily greater, and would produce more rapid changes and greater convulsions than now. This is a purely theoretical conclusion, by no means sure, and perhaps the very reverse of what really occurred. There

are two reasons for this belief which may be very briefly stated. After the earth's crust was once formed it cooled very slowly, and the crust became very gradually thicker. So far as the action of the molten interior on the crust may have produced convulsions, they should become not less but more violent as the crust becomes thicker. With a thin crust internal tensions will be more frequently relieved by fracture or bending, and the resulting disturbances will be *less* violent; but as the crust becomes thicker internal tensions will accumulate, and when relieved by fracture the disturbances will be *more* violent.

As regards storms and other aërial disturbances, these also would probably be less violent when the temperature of the whole surface was more uniform as well as warmer, and the atmosphere consequently so full of vapour as to prevent the sun's rays from producing the great inequalities of temperature that now prevail. It is these inequalities that cause the great aërial disturbances of our era, which arise from the heated surfaces of the bare plains and deserts of the sub-tropical and warm-temperate belts. In the equatorial belt (10° each side of the equator), where the heat is more uniform, and the surface generally well clothed with vegetation, tornadoes and hurricanes are almost unknown.

There remains only the action of the tides upon coasts and estuaries, which may have been greater in early geological times, if, as is supposed, the moon was then considerably nearer to the earth than it is now. But this is a comparatively unimportant matter as regards geological convulsions, because its maximum effects recur at short intervals and with great regularity, so that both vegetation and the higher forms of animal life would necessarily be limited to the areas which were beyond its influence.

It thus appears that so far from there being any

theoretical necessity for greater violence of natural forces in early geological times, there are some weighty reasons why the opposite should have been the case; while all the evidence furnished by the rocks themselves, and by the contours of the earth's surface, are in favour of a general uniformity, with, of course, considerable local variability.

It is interesting to note the very different explanations of the commonest features of the earth's surface given by the old and by the new theories. In every mountain region of the globe deep valleys, narrow ravines, and lofty precipices are of common occurrence, and these were, by the old school, almost always explained as being due to convulsions of nature. In ravines, we were taught that the rocks had been "torn asunder," while the mountains and the precipices were indications of "sudden fractures and upheavals of the earth's crust." On the new theory, these phenomena are found to be almost wholly due to the slow action of the most familiar every-day causes, such as rain, snow, frost, and wind, with rivers, streams, and every form of running water, acting upon rocks of varying hardness, permeability, and solubility. Every shower of rain falling upon steep hillsides or gentle slopes, while partially absorbed, to a large extent runs over the surface, carrying solid matter from higher to lower levels. Every muddy stream or flooded river shows the effect of this action. Day and night, month after month, year after year, this denudation goes on, and its cumulative effects are enormous. The material is supplied from the solid rocks, fractured and decomposed by the agency of snow and frost, or by mere variations of temperature, and primarily by those interior earth-movements which are continually cleaving, fissuring, and faulting the solid strata, and thus giving the superficial causes of denudation facilities for action. The amount and rate of this superficial

erosion and denudation of the earth's surface can be determined by the quantity of solid matter carried down by the rivers to the sea. This has been measured with considerable accuracy for several important rivers, and by comparing the quantity of matter, both in suspension and solution, with the area of the river basin, we know exactly the average amount of lowering of the whole surface per annum. It has thus been calculated that—

The Mississippi removes one foot of the surface of its basin in	. . .	.	6,000	years
,, Ganges	,,	,,	2,358	,,
,, Hoang Ho	,,	,,	1,464	,,
,, Rhone	,,	,,	1,528	,,
,, Danube	,,	,,	6,846	,,
,, Po	,,	,,	729	,,
,, Nith (in Scotland)	,,	,,	4,723	,,

The average of these rivers gives us 1 foot in 3000 years, or 1000 feet in 3,000,000 years as the lowering of the land by sub-aërial denudation; but, as Europe has a mean altitude of less than 1000 feet, it follows that at the present rate of denudation the whole of Europe would be reduced to nearly the sea-level in about 3,000,000 years. Before this method of measuring the rate of the lowering of continents was discovered by Mr Alfred Tylor in 1853, no one imagined that it was anything like so rapid; and, as 1,000,000 years is certainly a short period as compared with the whole geological record, it is clear that elevation must, on the whole, have always kept pace with the two lowering agencies—sinking and denudation. Again, as in every continent the areas occupied by plains and lowlands, where denudation is comparatively slow, are large as compared with the mountain areas,

where all the denuding agencies are most powerful, it is probable that most mountain ranges are being lowered at perhaps ten times the above average rate, and many mountain peaks and ridges perhaps a hundred times.

Examples of the rapidity of denudation as compared with earth-movements are to be found everywhere. In disturbed regions faults of many hundreds, and sometimes even thousands of feet, are not uncommon underground, greatly interfering with the work of the miner; yet there is often no inequality on the surface, indicating that the dislocation of strata has been caused by small and often-repeated movements, at such intervals that denudation has been able to remove the elevated portion as it arose. Again, when the strata are bent into great folds or undulations, it is only rarely that the tops of the folds correspond to ridges and the depressions to valleys. Frequently the reverse is the case, a valley running along the anticlinal line or structural ridge, while the synclinal or structural hollow forms a mountain top; while in other cases valleys cut across these structural features with little or no regard to them. This results from the fact that it is not mountains or mountain ranges, as we see them, which have been raised by internal forces; but a considerable area of country, already perhaps much dislocated by earth-movements, has been slowly raised till it became a kind of table-land. From its first elevation above the sea, however, it would have been exposed to rainfall, and the water flowing off in the direction of least resistance would have formed a number of channels radiating from the highest portion, and thus establishing the first outlines of a system of valleys, which go on deepening as the land goes on rising, often quite irrespective of the nature of the rocks beneath. This explains the close resemblance in the general arrangement of valleys

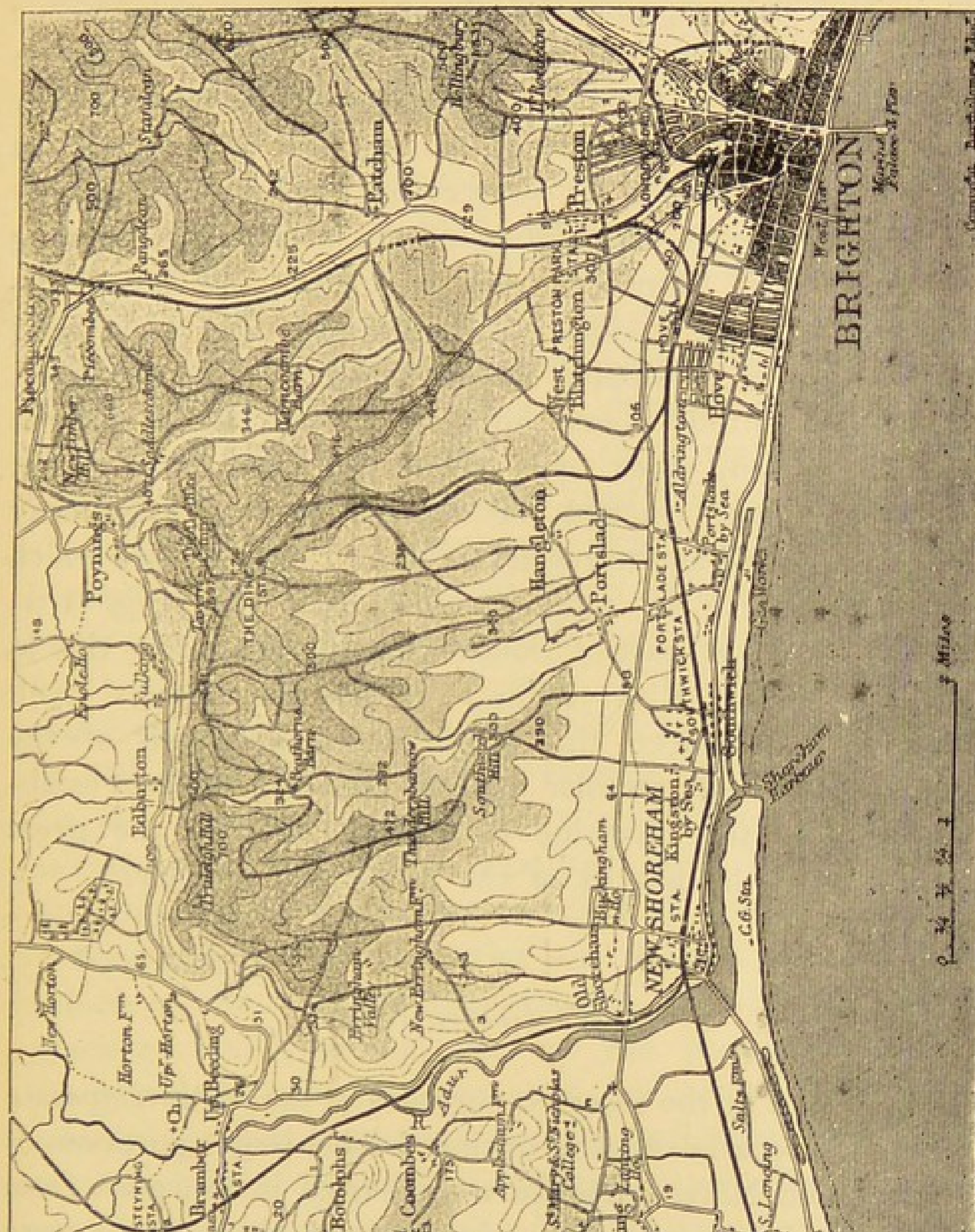


Fig. 101.—Contour Map showing the River Adur flowing through the South Downs
(The darkest portions are the most elevated)

in all high regions, as well as the very common phenomenon of a river crossing the main range of a mountain system by a deep gorge, for this merely shows that what is now the highest part of the range was at first lower than that where the river has its source, but has become higher by the more rapid degradation of the lateral ranges, owing to their being formed of rock which is more easily disintegrated. The various peculiarities of open valley and narrow gorge, of sloping mountain-side or lofty precipice, of rivers cutting across hills, as in the South Downs and at Clifton, when open plains by which they might apparently have reached the sea are near at hand, may be all explained as the results of those simple causes which are everywhere in action around us. (*See* Fig. 101, p. 357. Map of part of South Downs, illustrating this in the case of the River Adur.) It was Sir Charles Lyell who first convinced the whole scientific world of the efficacy of these familiar agents; and the secure establishment of this doctrine constitutes one of the great philosophical landmarks of the nineteenth century.

The Glacial Epoch

The proof of the recent occurrence in the north temperate zone of a glacial epoch, during which large portions of Europe and North America were buried in ice, may, from one point of view, be thought to prove that other agents than those now in operation have acted in past ages, and thus to disprove the main assumption of the uniformitarians. But, on the other hand, its existence has been demonstrated by those very methods which Sir Charles Lyell advocated—the accurate observation of what nature is doing now; while an ice age really exists at the present time in

Greenland, in the same latitude as nearly the whole of Sweden and Norway, which enjoy a comparatively mild climate, and over a still wider area in the South Polar Regions.

The first clear statement of the evidence for a former ice age was given, in 1822, by a Swiss engineer named Venetz. He pointed out that, where the existing glaciers have retreated, the rocks which they had covered are often rounded, smoothed, and polished, or grooved and striated in the direction of the glacier's motion; and that, far away from any existing glaciers, there were to be seen rocks similarly rounded, polished, and striated; while there also existed old moraine heaps exactly similar to those formed at present; and that these phenomena extended as far as the Jura range, on the flanks of which there were numbers of huge masses of rock, of a kind not found in those mountains, but exactly similar to the ancient rocks of the main Alpine chain. Hence, he concluded that glaciers formerly extended down the Rhone valley as far as the Jura, and there deposited those erratic blocks, the presence of which had puzzled all former observers.

Soon afterwards Charpentier and Agassiz devoted themselves to the study of the records left by the ancient glaciers; and from that time to the present a band of energetic workers in every part of the world have, by minute observation and reasoning, established the fact of the extension of glaciers, or ice-sheets, over a large portion of the north temperate zone, and have also determined the direction of their motion and the thickness of the ice in various parts of their course. These conclusions are now admitted by every geologist who has devoted himself to the subject, and are embodied in the various official geological surveys of the chief civilised countries; and as they constitute one of the most remarkable chapters

in the past history of the globe, and especially as this great change of climate occurred during the period of man's existence on the earth, a brief sketch of the facts must be here given.

There are four main groups of phenomena which demonstrate the former existence of glaciers in areas where they are now absent—(1) moraines, and glacial drifts or gravels; (2) smoothed, rounded, or planed rocks; (3) striæ, grooves, and furrows on rock-surfaces; (4) Erratics and perched blocks.

(1) Moraines are formed by all existing glaciers, consisting of the earth and rocks which fall upon the ice-rivers from the sides of the valleys through which they flow. The slow motion of the glacier carries these down with it, and they are deposited in great heaps where it melts. In some glaciers, where the tributary valleys are numerous and the debris that falls upon the ice is abundant, the whole of the lower part of the glacier for many miles is so buried in it that the surface of the ice cannot be seen, and in these cases there will be a continuous moraine formed across the valley where the glacier terminates. The characteristics of moraines are that they consist of varied materials, earth, gravel, and rocks of various sizes intermingled confusedly; and they often form mounds or ridges completely across a valley, except where the stream passes through it, while in other cases they extend laterally along the slopes of the hillsides, where, owing to the form of the valley, the glacier has shrunk laterally and left its lateral moraine behind it. In many cases huge blocks of rock rest on the very summit of a moraine, or, in the case of lateral moraines, on the very edge of a precipice in positions where no known agency but ice could have deposited them. These are called "perched blocks." Drifts or glacial gravels are deposits of material similar

to that forming the moraines, but spread widely over districts which have formerly been buried in ice. These are often partially formed of stiff clay, in which are imbedded quantities of smoothed and striated stones; but the great characteristics of all these ice-products is that the materials are not stratified—that is, sorted according to their fineness or coarseness, as is always the case when deposited by water, but are mingled confusedly together, the large stones being scattered all through the mass, and usually being quite as abundant at the top as at the bottom of the deposit. Such deposits are to be found all over the north and north-west of our islands, and are often well exhibited in railway cuttings; and wherever they are well developed, and the materials of which they consist differ from those forming the underlying rocks, they are an almost infallible indication of the former existence of a glacier or ice-sheet.

(2) The smoothed and rounded rocks, called in Switzerland *roches moutonnées*, from their resemblance at a distance to recumbent sheep, are present in almost all recently-glaciated mountainous countries, especially where the rocks are very hard. They are to be seen in all the higher valleys of Wales, the Lake District, and Scotland, and on examination are found to consist often of the hardest and toughest rocks. In other cases the rock forming the bed of the valley is found to be planed off smooth, even when it consists of hard crystalline strata thrown up at a high angle, and which naturally weathers into a jagged or ridged surface.

(3) The smoothed rocks are often found to be covered with numerous striæ, or scratches, deep grooves, or huge flutings, and these are almost always in the same direction, which is that of the course of the glacier. (*See* Fig. 104, p. 373. Ice-groovings at Barmouth.) They may often be traced in one direction for miles, and do not change

in accordance with the lesser inequalities of the valley, as they would certainly do had they been formed by water action. These striæ and smoothed rocks are often found hundreds or even thousands of feet above the floor of the valley, and in many cases a definite line can be traced above which the rocks are rugged and jagged, while below it they are all more or less rounded, smooth, or polished.

(4) Erratic blocks are among the most widespread and remarkable indications of glacial action, and they were the first that attracted the attention of men of science. The great plains of Denmark, Prussia, North Germany, and Russia are strewn with large masses of granite and hard metamorphic rocks, and these rest either on glacial drift or on quite different rocks of Secondary or Tertiary age. In parts of North Germany they are so abundant as to hide the natural surface, and they are often piled up in irregular heaps forming hills of granite boulders covered with forests of pine, birch, and juniper. Many of these blocks are more than a thousand tons weight, and almost all of them can be traced to the mountains of Scandinavia as their source. Many of the largest blocks have been carried farthest from the parent rock—a fact which is conclusive against their having been brought to their present position by the action of floods.

The most interesting and instructive erratic blocks are those found upon the slopes of the Jura, because they have been most carefully studied by Swiss and French geologists, and have all been traced to their sources in the Alpine chain. The Jura mountains consist wholly of Secondary limestones, and are situated opposite to the Bernese Alps, at a distance of about 50 miles. Along their slopes for a distance of 100 miles, and extending from their base to a height of 2000 feet above the Lake of Neuchâtel, are great numbers of rocks, some of them as large as

houses, and always quite different from that of which the Jura range is formed. These have all been traced to their parent rocks in various parts of the course of the old glacier of the Rhone, and, what is even more remarkable, their distribution is such as to prove that they were conveyed by a glacier and not by floating ice during a period of submergence. The rocks and other debris that fall upon a glacier from the two sides of its main valley form distinct moraines upon its surface, and however far the glacier may flow, and however much it may spread out where the valley widens, they preserve their relative position, so that whenever they are deposited by the melting of the glacier those that came from the north side of the valley will remain completely separated from those which came from the south side. It was this fact which convinced Sir Charles Lyell that the theory of floating ice, which he had first adopted, would not explain the distribution of the erratics, and he has given in his "Antiquity of Man" (4th ed., p. 344) a map showing the course of the blocks as they were conveyed on the surface of the glacier to their several destinations. Other blocks are found on the lower slopes of the Alpine chain towards Berne on one side and Geneva on the other, while the French geologists have traced them down the Rhone valley 70 miles from Geneva, and also more than 20 miles west of the Jura, thus proving that at the lowest portion of that chain the glacier flowed completely over it. In all these cases the blocks can be traced to a source corresponding to their position on the theory of glacier action. Some of these rocks have been carried considerably more than 200 miles, proving that the old glacier of the Rhone extended to this enormous distance from its source.

The Ice Age in the British Islands

In our own islands and in North America these various classes of evidence have been carefully studied, the direction of the glacial striæ everywhere ascertained, and all the more remarkable erratic blocks traced to their sources, with the result that the extent and thickness of the various glaciers and ice-sheets are well determined and the direction of motion of the ice ascertained. The conclusions arrived at are very extraordinary, and must be briefly indicated.

In Great Britain, during the earlier and later phases of the ice age, all the mountains of Scotland, the Lake District, and Wales produced their own glaciers, which flowed down to the sea. But at the time of the culmination of the Glacial Epoch the Scandinavian ice-sheet extended on the south-east till it filled up the Baltic Sea and spread over the plains of north-western Europe, and also filled up the North Sea, joining the glaciers of Scotland, forming with them a continuous ice-sheet from which the highest mountains alone protruded. At the same time, this Scottish ice-sheet extended into the Irish Sea, and united with the glaciers of the Lake District, Wales, and Ireland till almost continuous ice-sheets enveloped those countries also. Glacial striæ are found up to a height of 3500 feet in Scotland and 2500 feet in the Lake District and in Ireland; while the Isle of Man was completely overflown, as shown by glacial striæ on the summit of its loftiest mountains. Erratics from Scandinavia are found in great quantities on Flamborough Head, mixed with others from the Lake District and Galloway, showing that two ice-streams met here from opposite directions; and the chalk cliffs at Thornwick are covered with a thick layer of glacial mud and clay containing rock fragments which must have been brought across the North Sea by the Scandinavian ice-

sheet, since similar rocks are only found in the Scandinavian peninsula. These glacial deposits are very striking from their contrast in colour with the chalk on which they rest. Similar deposits of great thickness overlying the Upper Oolite a little farther north also contain Scandinavian

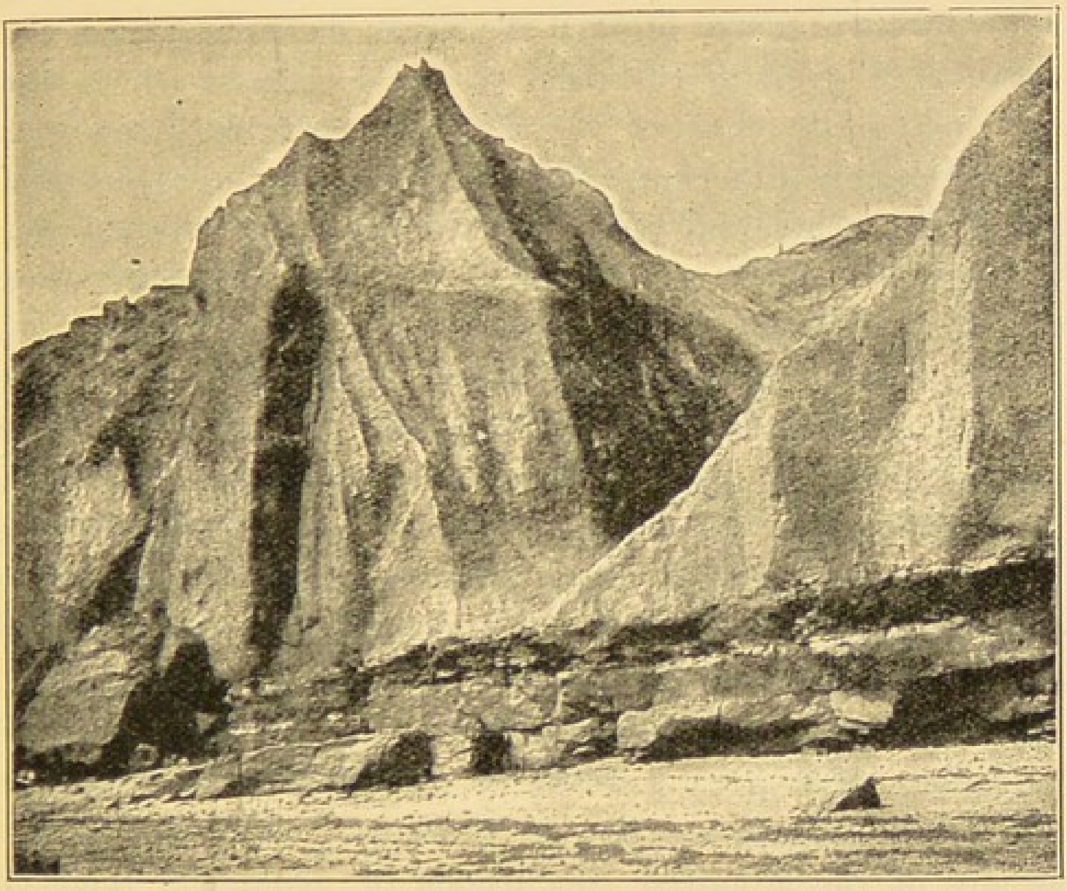


Fig. 102.—Cliffs and Peaks of Boulder Clay on Upper Oolite in Yorkshire

erratics, and they have been weathered into peaks and precipices which perfectly simulate the summits of some of the Alpine mountain ranges.* (Fig. 102.)

Erratics from Scotland are also found in the Lake District, in North Wales, in the Isle of Man, and in

* This photograph was taken by Mr Bingley, who kindly allowed me to reproduce it (with many others) in my "Studies Scientific and Social."

Ireland, from which the direction of the moving ice can be determined. Great numbers of local rocks have also been carried into places far from their origin, and in every case this displacement is in the direction of the flow of the ice as ascertained by the other evidence—never in the opposite direction. Each great mountain area had, however, its own centre of local dispersal, depending upon the position of greatest thickness of the ice-sheet, which was not necessarily that of the highest mountains, but was approximately the centre of the main area of glaciation. Thus the centre of the North Wales ice-sheet was not at Snowdon, but over the Arenig mountains, which thus became a local centre of dispersal of erratics. In Ireland, the mountains being placed around the coasts, the great central plain became filled with ice, which, continually accumulating, formed a huge ice-dome whose outward pressure caused motion in all directions till checked by the opposing motion of the great Scandinavian ice-sheet. This strange fact has been demonstrated by the work of the Irish Geological Survey and by many local geologists, and is universally accepted by all who have studied the evidence. The great outlines of the phenomena of the ice age in our islands are now as thoroughly well established as any of the admitted conclusions of geological science. In our own country the ice extended more or less completely over the whole of the midland counties and as far south as the Thames Valley.

The Ice Age in North America

When we cross the Atlantic the phenomena are equally remarkable. The whole of the north-eastern United States and Canada were buried in an ice-sheet of enormous thick-

ness and extent. It spread southward as far as New York, and in an irregular line inland by Cincinnati to St Louis on the Mississippi. The whole of the region to the north of this line is covered with a deposit of drift, often of enormous thickness, while embedded in the drift or scattered over its surface are numbers of blocks and rock-masses, often formed of materials quite foreign to the bed-rock of the district. These erratics have in many cases been traced to their sources, sometimes 600 miles away, and the study of these, and of the numerous grooved and striated rocks, show that the centre of dispersal was far north of the Alleghanies and its outliers, and, as in the case of Ireland, must have consisted of a huge dome of ice situated over the plateau to the north of the great lakes, in what must have been an area of great snowfall combined with a very low temperature. The maximum thickness of this great ice-sheet was at least a mile over a considerable portion of its area, as proved by the glacial deposits found on the summit of Mount Washington at an altitude of nearly 6000 feet, while the centre of motion was a considerable distance to the north-west, where the ice must have reached a still greater altitude.

The Demonstration of the Ice Age in the Northern Hemisphere

The complete general agreement of the conclusions reached by four different sets of observers in four different areas — Switzerland, North-Western Europe, the British Isles, and North America—after fifty years of continuous research, and after every other less startling theory had been put forth and rejected as wholly inconsistent with the phenomena to be explained, renders it as certain as any

conclusion from indirect evidence can be, that a large portion of the north temperate zone, now enjoying a favourable climate and occupied by the most civilised nations of the world, was, at a very recent epoch geologically speaking, completely buried in ice, just as Greenland is now. How recently the ice has passed away is shown by the perfect preservation of innumerable moraines, perched blocks, erratics, and glaciated rock surfaces, showing that but little denudation has occurred to modify the surface; while undoubted relics of man found in glacial or interglacial deposits prove that it occurred during the human period. It is clear that man could not have lived in any area during the time it was buried in the ice-sheet, while any indications of his presence at an earlier period would almost certainly be destroyed by the enormous abrading and grinding power of the ice.

Besides the areas above referred to, there are widespread indications of glaciation in parts of the world where a temperate climate now prevails. In the Pyrenees, Caucasus, Lebanon, and Himalayas glacial moraines are found far below the lower limits they now attain. In the Southern Hemisphere similar indications are found in New Zealand, Tasmania, and the southern portion of the Andes; but whether this cold period was coincident with that of the Northern Hemisphere we have at present no means of determining, nor even whether they were coincident among themselves, since it is quite conceivable that they may have been due to local causes, such as greater elevation of the land, and not to any general cause acting throughout the south temperate zone.

In the north temperate zone, however, the phenomena are so widespread and so similar in character, with only such modifications as are readily explained by proximity to, or remoteness from, the ocean, that we are almost sure they

must have been simultaneous, and have been due to the same general causes, though perhaps modified by local changes in altitude and consequent modification of winds or ocean currents. The time that has elapsed since the glaciation of the Northern Hemisphere passed away is, geologically, very small indeed, and has been variously estimated at from 20,000 to 100,000 years. At present the smaller period is most favoured by geologists, but the duration of the ice age itself, including probably one or more interglacial mild periods, is admitted to be much longer, and probably to approach the higher figure above given.

The undoubted fact, however, that a large part of the north temperate zone has been recently subjected to so marvellous a change of climate is of immense interest from many points of view. It teaches us in an impressive way how delicate is the balance of forces which renders what are now the most densely peopled areas habitable by man. We can hardly suppose that even the tremendously severe ice age of which we have evidence is the utmost that can possibly occur; and, on the other hand, we may anticipate that the condition of things which in earlier geological times rendered even the polar regions adapted for a luxuriant woody vegetation, may again recur, and thus vastly extend the area of our globe which is adapted to support human life in abundance and comfort. In the endeavour to account for the change of climate and of physical geography which brought about so vast a change, and then, after a period certainly approaching, and perhaps greatly exceeding 100,000 years, caused it to pass away, some of the most acute and powerful intellects of our day have exerted their ingenuity; but, so far as obtaining general acceptance for the views of any one of them, altogether in vain. There seems reason to believe,

however, that the problem is not an insoluble one; and when the true cause is reached it will probably carry with it the long-sought datum from which to calculate with some rough degree of accuracy the duration of geological periods. But, whether we can solve the problem of its cause or no, the demonstration of the recent occurrence of a glacial epoch or great ice age, with the determination of its main features over the Northern Hemisphere, will ever rank as one of the great scientific achievements of the nineteenth century.*

The Antiquity of Man

Following the general acceptance of a glacial epoch by about twenty years, but to some extent connected with it, came the recognition that man had existed in Northern Europe along with numerous animals which no longer live there—the mammoth, the woolly rhinoceros, the wild horse, the cave-bear, the lion, the sabre-toothed tiger, and many others—and that he had left behind him, in an abundance of rude flint implements, the record of his presence. Before that time geologists, as well as the whole educated world, had accepted the dogma that man only appeared upon the earth when both its physical features and its animal and vegetable forms were exactly as we find them to-day; and this belief, resting solely on negative evidence, was so strongly and irrationally main-

* I have myself given what seems to me an adequate solution of the problem of the cause of the glacial epoch in Chapters VIII. and IX. of my "Island Life." I adopt, generally, the views of the late Dr James Croll, but I have introduced some important modifications which obviate most of the objections to his theory, which I show to be in harmony with all the available facts. I have also given a somewhat fuller account of the more interesting glacial phenomena, illustrated by numerous photographs, in Chapters IV., V., and VI., vol. i. of my "Studies Scientific and Social."

tained that the earlier discoveries could not get a hearing. A careful but enthusiastic French observer, M. Boucher de Perthes, had for many years collected with his own hands, from the great deposits of old river gravels in the valley of the Somme, near Amiens, abundance of large and well-formed flint implements. (*See* Fig. 103.) In 1847 he published an account of them, but nobody believed his statements till, ten years later, Dr Falconer, and, shortly afterwards, Professor Prestwich and Mr John Evans, examined the collections and the places where they were found, and were at once convinced of their importance; and their testimony led to the general acceptance of the doctrine of the great antiquity of the human race. From that time researches on this subject have been carried on by many earnest students, and have opened up a number of altogether new chapters in human history.

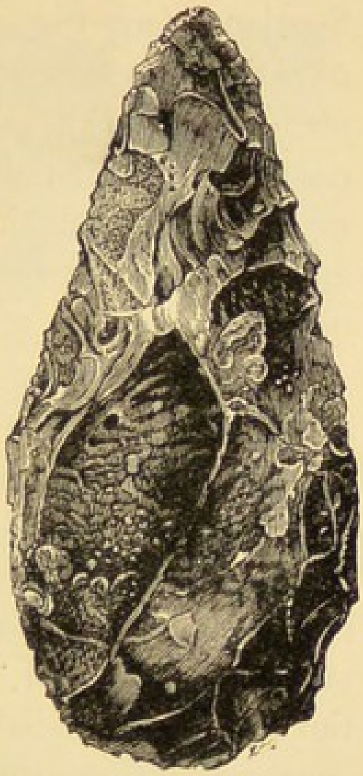


Fig. 103.—Palæolithic Flint Implement, Amiens
(From Lyell's "Elements of Geology." By permission of Mr John Murray)

So soon as the main facts were established, many old records of similar discoveries were called to mind, all of which had been ignored or explained away on account of the strong prepossession in favour of the very recent origin of man. In 1715 flint weapons had been found in excavations near Gray's Inn Lane, along with the skeleton of an elephant. In 1800 another discovery was made, in Suffolk, of flint weapons and the remains of extinct animals in the same deposits. In 1825 Mr McEnery of Torquay discovered worked flints, along with the bones and teeth

of extinct animals in Kent's cavern. In 1840 a good geologist confirmed these discoveries and sent an account of them to the Geological Society of London, but the paper was rejected as being too improbable for publication! All these discoveries were laughed at or explained away, as the glacial striæ and grooves so beautifully exhibited in the Vale of Llanberris and elsewhere in Wales and Scotland (*see* Fig. 104) were at first endeavoured to be explained as the wheel-ruts caused by the chariots of the ancient Britons! These, combined with numerous other cases of the denial of facts on *à priori* grounds, have led me to the conclusion that, whenever the scientific men of any age disbelieve other men's careful observations without inquiry, the scientific men are *always* wrong.

Even after these evidences of man's great antiquity were admitted, strenuous efforts were made to minimise the time as measured by years; and it was maintained that man, although undoubtedly old, was entirely post-glacial. But evidence has been steadily accumulating of his existence at the time of the glacial epoch, and even before it; while two discoveries of recent date seem to carry back his age far into pre-glacial times. These are, first, the human cranium, bones, and works of art which have been found more than 100 feet deep in the gold-bearing gravels of California, associated with abundant vegetable remains of extinct species, and overlaid by four successive lava streams from long extinct volcanoes. The other case is that of rude stone implements discovered by a geologist of the Indian Survey in Burma in deposits which are admitted to be of at least Pliocene age. In both these cases the evidence is disputed by some geologists, who seem to think that there is something unscientific, or even wrong, in admitting evidence that would prove the Pliocene age of any other animal to be equally valid in the case of

man. There is assumed to be a great improbability of his existence earlier than the very end of the Tertiary epoch. But all the indications drawn from his relations to the anthropoid apes point to an origin far back in Tertiary time. For each one of the great apes—the gorilla, the chimpanzee, the orang, and even the gibbons—resemble

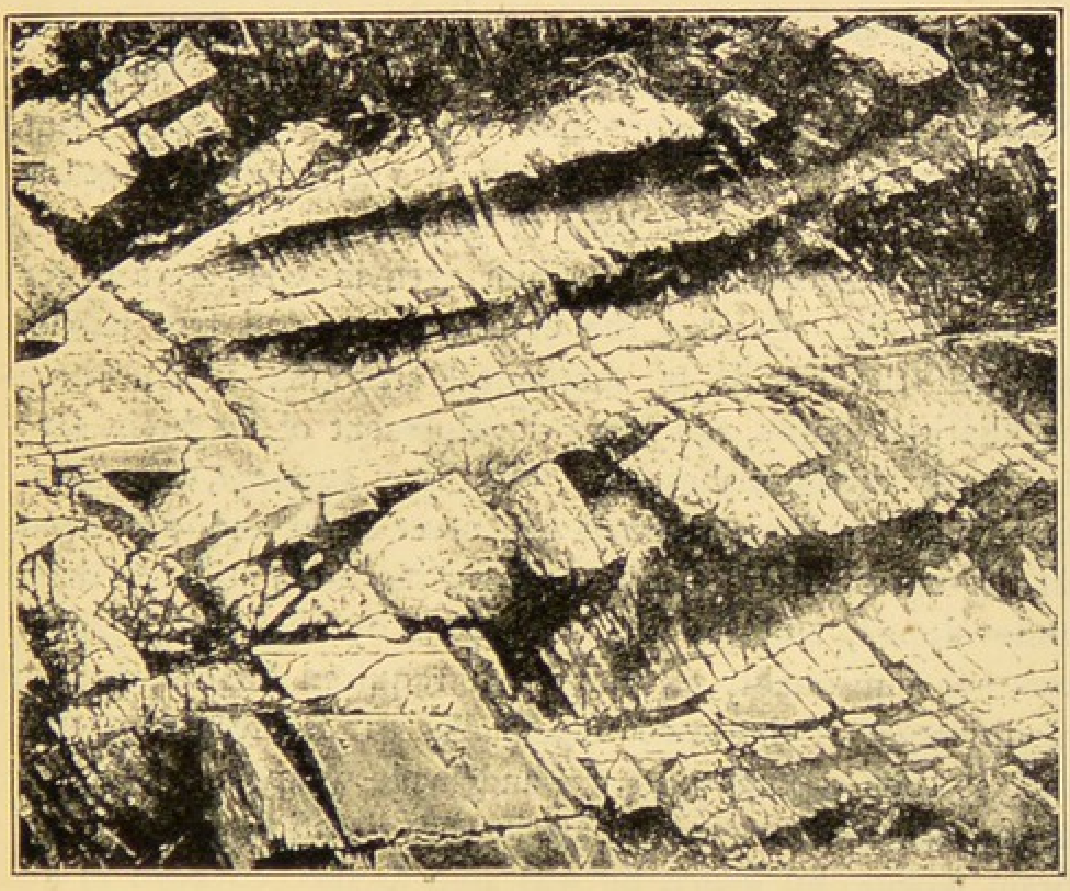


Fig. 104.—Ice-groovings on steep rock, Barmouth

man in certain features more than do their allies, while in other points they are less like him. Now, if man has been developed from a lower animal form, we must seek his ancestors not in the direct line between him and any of the apes, but in a line towards a common ancestor to them all; and this common ancestor must certainly date back to the early part of the Tertiary epoch, because in

the Miocene period anthropoid apes not very different from living forms have been found fossil.

There is, therefore, no improbability whatever in the existence of man in the later portions of the Tertiary period, and we have no right, scientifically, to treat any evidence for his existence in any other way than the evidence for the existence of other animal types.*

It has been argued by some writers that, as no other living species of mammal goes back farther than the Newer Pliocene, therefore man is probably no older. But it is forgotten that the difference of man from the apes is not only specific but at least of generic or of family rank, while some naturalists place him even in a separate order of mammalia. Besides the erect posture and free hands, with all the details of anatomical structure which these peculiarities imply, the great development of his brain pre-eminently distinguishes him. We may suppose, therefore, that when he had reached the erect form and possessed all the external appearance of man, his brain still remained undeveloped, and the time occupied by this development was not improbably equal to that required for the specific modification of the lower mammalia. It is often forgotten that so soon as man used fire and made weapons all further useful modification would be in the direction of increased brain power, by which he was able to succeed both in his struggle against the elements and with the lower animals. There is, therefore, no improbability in finding the remains

* In addition to the two separate evidences above alluded to as proving the pre-glacial existence of man, we must now add a third, in the discovery a few years back by Mr Harrison of Ightham of great numbers of very rude flint implements on the high chalk plateau north of Sevenoaks. They are so distinct from all those previously termed palæolithic, and the position of the gravel in which they occur indicates such a much greater antiquity, that they have been termed eolithic, and the late Professor Prestwich, who specially studied them, considered, that on strict geological evidence they were almost certainly of pre-glacial age.

or the implements of a low type of man in the early Pliocene period.

The certainty that man co-existed with many now extinct animals, and the probability of our discovering his remains in undoubted Tertiary strata, constitutes an immense advance on the knowledge and beliefs of our forefathers, and must, therefore, rank among the prominent features in the scientific progress of the nineteenth century.

CHAPTER XVII

EVOLUTION AND NATURAL SELECTION

"Enkindled in the mystic dark,
  Life built herself a myriad forms,
And, flashing its electric spark
  Through films, and cells, and pulps, and worms,
Flew shuttlewise above, beneath,
  Weaving the web of life and death."

MATHILDE BLIND.

WE now approach the subject which, in popular estimation, and perhaps in real importance, may be held to be the great scientific work of the nineteenth century — the establishment of the general theory of evolution, by means of the special theory of the development of the organic world through the struggle for existence and its necessary outcome, Natural Selection. Although in the eighteenth century Buffon, Dr Erasmus Darwin, and the poet Goethe, had put forth various hints and suggestions pointing to evolution in the organic world, which they undoubtedly believed to have occurred, no definite statement of the theory had appeared till early in the nineteenth century, when Laplace explained his views as to the evolution of the solar system by his celebrated Nebular Hypothesis; and about the same time Lamarck published his "Philosophie Zoologique," containing an elaborate exposition of his theory of the progressive development of animals and plants. But this theory gained few converts among naturalists, partly because Lamarck was before his time, and also because the causes he alleged did not seem adequate to produce the wonderful adaptations we everywhere see in

nature. During the first half of the present century, owing to the fact that Brazil, South Africa, and Australia then became for the first time accessible to European collectors, the treasures of the whole world of nature were poured in upon us so rapidly that the comparatively limited number of naturalists were fully occupied in describing the new species and endeavouring to discover true methods of classification. The need of any general theory of how species came into existence was hardly felt; and there was a general impression that the problem was at that time insoluble, and that we must spend at least another century in collecting, describing, and classifying before we had any chance of dealing successfully with the origin of species. Yet the subject of evolution was ever present to the more philosophic thinkers, though the great majority of naturalists and men of science held firmly to the dogma that each species of animal and plant was a distinct creation, but how produced was admitted to be both totally unknown and almost if not quite unimaginable.

The vague ideas of those who favoured evolution were first set forth in systematic form, with much literary skill and scientific knowledge, by the late Robert Chambers in 1844, in his anonymous volume, "Vestiges of the Natural History of Creation." He passed in review the stellar and solar systems, adopted the Nebular Hypothesis, and sketched out the geological history of the earth, with continuous progression from lower to higher forms of life. After describing the peculiarities of the lower plants and animals, dwelling upon those features which seemed to point to a natural mode of production as opposed to an origin by special creation, the author set forth with much caution the doctrine of progressive development resulting from "an impulse which was imparted to the forms of life, advancing them in definite lines, by generation, through

grades of organisation terminating in the highest plants and animals." The reasonableness of this view was urged through the rest of the work; and it was shown how much better it agreed with the various facts of nature and with the geographical distribution of animals and plants than the idea of the special creation of each distinct species.

It will be seen from this brief outline that there was no attempt whatever to show *how* or *why* the various species of animals and plants acquired their peculiar forms, colours, habits, and instincts, but merely an argument in favour of the reasonableness of the fact of progressive development, from one species to another, through the ordinary processes of generation. The book was what we should now call mild in the extreme. It was serious and even religious in tone, and calculated in this respect to disarm the opposition even of the most orthodox theologians; yet it was met with just the same storm of opposition and indignant abuse which assailed Darwin's work fifteen years later. As an illustration of the state of scientific opinion at this time, it may be mentioned that so great a man as Sir John Herschel, at a scientific meeting in London, spoke strongly against the book for its advocacy of so great a scientific heresy as the Theory of Development.

I well remember the excitement caused by the publication of the "Vestiges" and the eagerness and delight with which I read it. Although I saw that it really offered no explanation of the process of change of species, yet the view that the change was effected, not through any unimaginable process, but through the known laws and processes of reproduction, commended itself to me as perfectly satisfactory, and as affording the first step towards a more complete and explanatory theory. It seems now a most amazing thing that even to argue for this first step was accounted a heresy, and was almost universally con-

demned as being opposed to the teachings of both science and religion!

The book was, however, as great a success as, later on, was Darwin's "Origin of Species." Four editions were issued in the first seven months, and by 1860 it had reached the eleventh edition, and about 24,000 copies had been sold. It is certain that this work did great service in familiarising the reading public with the idea of evolution, and thus preparing them for the more complete and efficient theory laid before them by Darwin.

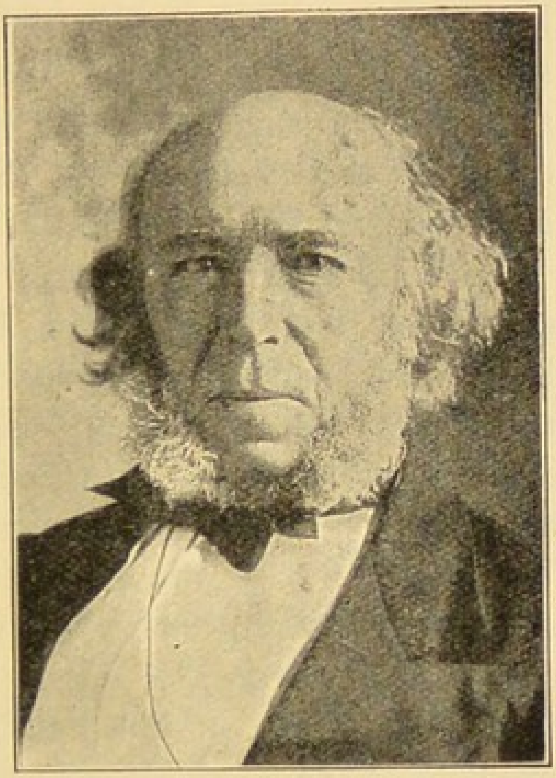


Fig. 105.—Herbert Spencer

During the fifteen years succeeding the publication of the "Vestiges" many naturalists expressed their belief in the progressive development of organic forms; while in 1852 Herbert Spencer published his essay contrasting the theories of Creation and Development with such skill and logical powers as to carry conviction to the minds of all unprejudiced readers; but none of these writers suggested any definite theory of *how* the change of species actually occurred. That was first done in 1858; and in connection with it I may, perhaps, venture to give a few personal details.

Ever since I read the "Vestiges" I had been convinced that development took place by means of the ordinary process of reproduction; but though this was widely

admitted, no one had set forth the various kinds of evidence that rendered it almost a certainty. I endeavoured to do this in an article written at Sarawak in February 1855, which was published in the following September in the "Annals of Natural History." Relying mainly on the well-known facts of geographical distribution and geological succession, I deduced from them the law, or generalisation, that "every species has come into existence coincident both in space and time with a pre-existing, closely allied species"; and I showed how many peculiarities in the affinities, the succession, and the distribution of the forms of life were explained by this hypothesis, and that no important facts contradicted it.

Even then, however, I had no conception of *how* or *why* each new form had come into existence with all its beautiful adaptations to its special mode of life; and though the subject was continually being pondered over, no light came to me till three years later (February 1858) under somewhat peculiar circumstances. I was then living at Ternate in the Moluccas, and was suffering from a rather severe attack of intermittent fever, which prostrated me for several hours every day during the cold and succeeding hot fits. During one of these fits, while again considering the problem of the origin of species, something led me to think of Malthus' "Essay on Population" (which I had read about ten years before), and the "positive checks"—war, disease, famine, accidents, etc.—which he adduced as keeping all savage populations nearly stationary. It then occurred to me that these checks must also act upon animals and keep down their numbers; and as they increase so much faster than man does, while their numbers are always very nearly or quite stationary, it was clear that these checks in their case must be far more powerful, since a number almost equal to the whole increase must be cut off by them every year.

While vaguely thinking how this would affect any species, there suddenly flashed upon me the idea of *the survival of the fittest*—that the individuals removed by these checks must be, on the whole, *inferior* to those that survived. Then, considering the *variations* continually occurring in every fresh generation of animals or plants, and the changes of climate, of food, of enemies always in progress, the whole method of specific modification became clear to me, and in the two hours of my fit I had thought out the main points of the theory. That same evening I sketched out the draft of a paper; in the two succeeding evenings I wrote it out, and sent it by the next post to Mr Darwin.* I fully expected it would be as new to him as it was to myself, because he had informed me by letter that he was engaged on a work intended to show in what way species and varieties differ from each other, adding, "my work will not fix or settle anything." I was therefore surprised to find that he had really arrived at the very same theory as mine long before (in 1844), had worked it out in considerable detail, and had shown the MSS. to Sir Charles Lyell and Sir Joseph Hooker; and on their recommendation my paper and sufficient extracts from his MSS. work were read at a meeting of the Linnean Society in July of the same year, when the theory of Natural Selection or survival of the fittest, was first made known to the world. But it received little attention till Darwin's great and epoch-making book appeared at the end of the following year.

To give any adequate account of the nature and extent of the evidence on which Darwin founded his conclusions is impossible here; but a very brief statement of the fundamental facts and of the chief steps in the argument may be attempted for the information of those

* These two papers are reprinted in my "Natural Selection and Tropical Nature."

who have not read any works specially dealing with the subject.

The first great fact in nature which we have to take note of is the enormous powers of increase of all organisms. Many of our small birds live fifteen or twenty years and lay from four to ten or twelve eggs or even more, some of them having two broods a year. But if all the offspring of one pair lived so long, and their descendants did the same, we should have in ten years 200,000,000 birds from each original pair. Many other creatures breed much more rapidly, but as the whole population of wild animals is, on the average, stationary, it is evident that all the young must die off each year before they can breed, until the death of the parents makes room for two of them.

From this fact arises what is termed "the struggle for existence." Every animal tries to live, and those that die every year are almost all killed by accidents or by disease, by enemies or by cold and hunger; while those that survive do so because they are able, in some way or other, to escape these various dangers—being stronger or swifter, more wary, more healthy, or better clad than their fellows—that is to say, the fittest (on the whole) live, the less fit die. This is the great law of the "survival of the fittest," or, as Darwin termed it, "natural selection." It is evident that every race of plants or animals is thus kept up to the standard of efficiency necessary to maintain life under all the dangers to which it is exposed, and not only to preserve its own existence, but to produce and rear to maturity a sufficiency of healthy offspring.

The next great natural fact to be considered is variation, combined with heredity. Though all animals and plants may be said to produce their like, yet all their offspring are not identically alike, but differ considerably among

themselves and from their parents. Every large family of children, every litter of kittens or of puppies, demonstrates this fact. It is this constant production of *variations* that has enabled us to improve our cultivated plants and domesticated animals to such a wonderful extent that if we did not know the exact process it would seem incredible. The fantail, the tumbler, and the pouter have thus been produced from the common wild rock-pigeon; while the greyhound, the pointer, the spaniel, and the bull-dog have been bred from some of the various wild dogs, none of which resemble these domestic breeds. Exactly similar variations constantly occur among wild as among domestic animals, and it is found that every part of the body and all the mental and physical faculties vary both separately and together, so that among a few hundreds of individuals taken at random a variation of from 20 to 30 per cent. will usually be found in the degree of development of all these characteristics. This enables us, by selection, to modify every part and every faculty in the way we desire.

The last great natural fact we have to notice is that the world in which all organisms live is itself continually changing, though to us almost imperceptibly, as has been shown in the last chapter. Sea and land change places in the course of ages; mountains are worn away into lowlands, while plains are slowly raised into lofty plateaux; climate also changes, from cold to warm, from damp to dry, from uniform to changeable, or the reverse, and these changes inevitably lead to migrations of plants and animals. They thus become exposed to new conditions; they may be compelled to live on new kinds of food; must endure a colder or a more arid climate; or must be able to escape from new and more dangerous enemies. Variation now comes into play and enables some of the best adapted to

pass successfully through the ordeal, which is the more easy because the change is usually very slow. Each year the fittest survive, and as some of their offspring inherit their parents' fitness while others often surpass them, and as this goes on for hundreds or thousands of generations, the race becomes continually modified into adaptation to the new conditions, and thus becomes often so changed in size, shape, colour, constitution, or habits as to form what we term a "new species." In this very gradual but very simple way nature provides for new kinds of animals and plants to continually replace the earlier ones when changed conditions render the former unable to survive. Hence arises that beautiful adaptation we see everywhere in nature, each species seeming to be so formed as to be able to live in the place where it is found (and sometimes nowhere else) and to escape all the dangers to which it is either constantly or periodically exposed.

This is "natural selection" or "the survival of the fittest," and its great feature is that it is founded on four groups of natural facts which are absolutely indisputable—rapid multiplication of the individuals of every species; struggle for existence; continual and universal variations; and equally universal but very slow change of conditions—while the result of the combined action of all these groups of facts in producing incessant and harmonious changes in the form, structure, colour, or habits of animals and plants is a logical necessity. It is this logical completeness of the theory, together with the wealth of facts by which it was supported, that led to its general acceptance by all classes of thinkers.

We may best attain to some estimate of the greatness and completeness of Darwin's work by considering the vast change in educated public opinion which it rapidly and permanently effected. What that opinion was before

it appeared is shown by the fact that neither Lamarck, nor Herbert Spencer, nor the author of the "Vestiges," had

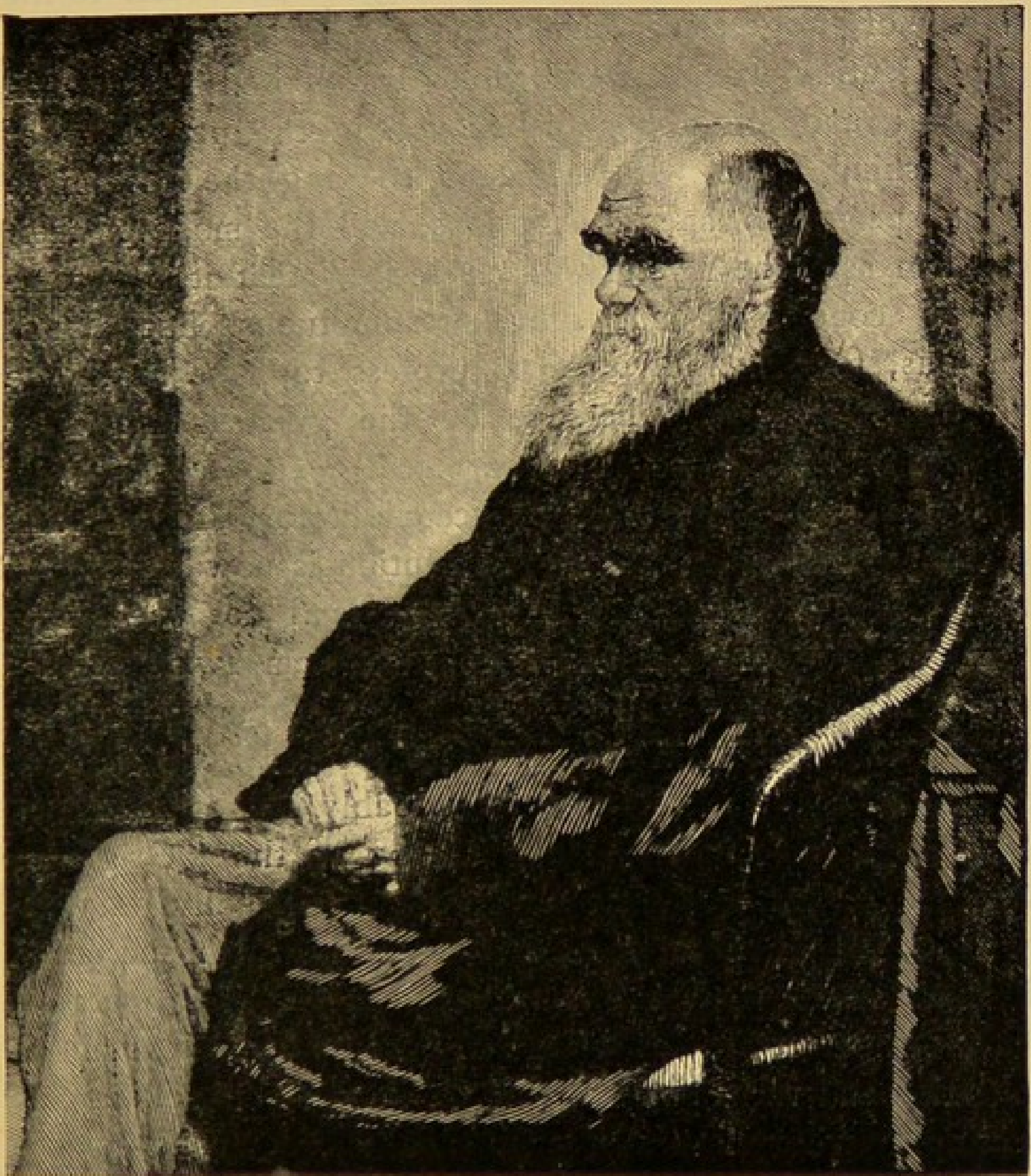


Fig. 106.—Darwin
(From a Photograph by Captain Darwin, R.E.)

been able to make any impression upon it. The very idea of progressive development of species from other species was held to be a "heresy" by such great and liberal-

minded men as Sir John Herschel and Sir Charles Lyell; the latter writer declaring, in the earlier editions of his great work, that the facts of geology were "fatal to the theory of progressive development." The whole literary and scientific worlds were violently opposed to all such theories, and altogether disbelieved in the possibility of establishing them. It had been so long the custom to treat species as special creations, and the mode of their creation as "the mystery of mysteries," that it had come to be considered not only presumptuous, but almost impious, for any individual to profess to have lifted the veil from what was held to be the greatest and most mysterious of Nature's secrets.

But what is the state of educated literary and scientific opinion at the present day! Evolution is now universally accepted as a demonstrated principle, and not one single writer of the slightest eminence that I am aware of declares his disbelief in it. This is, of course, partly due to the colossal work of Herbert Spencer; but for one reader of his works there are probably ten of Darwin's, and the establishment of the theory of the "Origin of Species by Means of Natural Selection" is wholly Darwin's work. That book, together with those which succeeded it, have so firmly established the doctrine of progressive development of species by the ordinary processes of multiplication and variation, that there is now, I believe, scarcely a single living naturalist who doubts it. What was a "great heresy" to Sir John Herschel in 1845, and "the mystery of mysteries" down to the date of Darwin's book, is now the common knowledge of every clever schoolboy and of everyone who reads even the newspapers. The only thing discussed now is not the fact of evolution—that is admitted—but merely whether or no the causes alleged by Darwin are themselves sufficient to explain

evolution of species, or require to be supplemented by other causes, known or unknown. Probably so complete a change of educated opinion on a question of such vast difficulty and complexity was never before effected in so short a time. It not only places the name of Darwin on a level with that of Newton, but his work will always be considered as one of the greatest, if not the very greatest, of the scientific achievements of the nineteenth century, rich as that century has been in great discoveries in every department of physical science.

CHAPTER XVIII

POPULAR DISCOVERIES IN PHYSIOLOGY

"Recluse, th' interior sap and vapour dwells,
In nice transparence of minutest cells."

H. BROOKE.

THE science of physiology, which investigates the complex phenomena of the motions, sensations, growth, and development of organisms, is almost wholly the product of the present century; but with the exception of a few fundamental conceptions, it has been an almost continuous growth by small increments, and offers few salient points of popular interest, or which can be made intelligible to the general reader.

The first of the great fundamental conceptions referred to is the cell-theory, which was definitely established for plants in 1838, and immediately afterwards for animal structures. The theory is that all the parts and tissues of plants and animals are built up of cells, modified in form and function in an infinite variety of ways, but to be traced in the early stages of growth, alike of bone and muscle, nerve and blood-vessel, skin and hair, root, wood, and flower. (Fig. 107.) And, further, that all organisms originate in simple cells, which are almost identical in form and structure, and which thus constitute the fundamental unit of all living things.

The second great generalisation is what has been termed the recapitulation theory of development. Every animal or plant begins its existence as a cell, which develops by a

process of repeated fission and growth into the perfect form. But if we trace the different types backward we find that we come to a stage when the embryos of all the members of an order, such as the various species of ruminants are undistinguishable; earlier still all the members of a class, such as the mammalia, are equally alike, so that the embryos of a sheep and a tiger would be almost identical; earlier still all vertebrates, a lizard, a bird, and a monkey, are equally undistinguishable. Thus in its progress from the cell to the perfect form every animal recapitulates, as it were, the lower forms upon its line of descent, thus affording one of the strongest indirect proofs of the theory of evolution. The earliest definite result of cell-division is to form what is termed the "gastrula," which is a sack with a narrow mouth, formed of two layers of cells. All the higher animals without exception, from mollusc to man, go through this "gastrula" stage, which again indicates that all are descended from a common ancestral form of this general type.

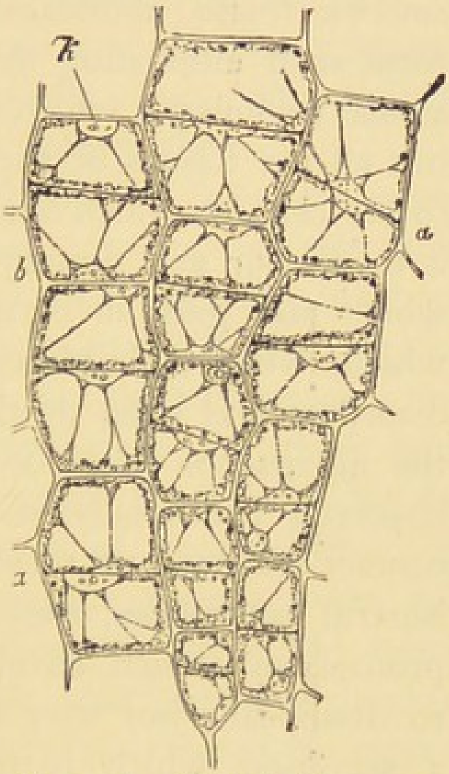


Fig. 107.—Cells in Stem of Bean (× 300)

One other physiological discovery is worth noting here, both on account of its remarkable nature and because it leads to some important conclusions in relation to the zymotic diseases. Quite recently it has been proved that the white corpuscles of the blood, whose function was previously unknown, are really independent living organisms. They are produced in large numbers by the spleen, an organ

which has long been a puzzle to physiologists, but whose function and importance to the organism seem to be now made clear. They are much smaller and less numerous than the red blood globules; they move about quite independently; and they behave in a manner which shows that they are closely allied to, if not identical with, the amœbæ found abundantly in stagnant water, and which form such interesting microscopic objects. These minute animal organisms, which inhabit not only our blood-vessels but all the tissues of the body, have an important function to perform, on which our very lives depend. This function is to devour and destroy the bacteria or germs of disease which may gain an entrance to our blood or tissues, and which, when their increase is unchecked, produce various disorders and even death. Under the higher powers of the microscope the leucocytes, as they are termed, can be observed continually moving about, and on coming in contact with any of these bacteria or their germs, or other hurtful substances, they send out pseudopodia from their protoplasm, which envelops the germ and soon causes it to disappear; but they also appear sometimes to produce a secretion which is injurious to the bacteria, and so destroys them, and these may perhaps be distinct organisms.

It seems probable, and, in fact, almost certain, that so long as we live in tolerably healthy conditions these leucocytes (or phagocytes as they are sometimes called from their function of devouring injurious germs) are able to deal with all disease germs which can gain access to our system; but, when we live in impure air, or drink impure water, or feed upon unwholesome food, our system becomes enfeebled, and our guardian leucocytes are unable to destroy the disease germs that gain access to our organism: the latter then increase rapidly, and are in many cases able to destroy us.

We learn from this marvellous discovery that, so long as we live simply and naturally and obey the well-known laws of sanitation, so as to secure a healthy condition of the body, the more dreaded zymotic diseases will be powerless against us. But if we neglect these laws of health, or allow of conditions which compel large bodies of our fellow-men to neglect them, these disease germs will be present in such quantities in the air and the water around us that even those who personally live comparatively wholesome lives will not always escape them.

We learn, too, another lesson from this latest discovery of the secrets of the living universe. Just as we saw how, physically, dust was so important that not only much of the beauty of nature but the very habitability of our globe depended upon it, so we now find that the most minute and most abundant of all organisms are those on which both our means of life and our preservation from death are dependent; for these minute bacteria of various kinds are present everywhere—in the air, in the water, in the soil under our feet. Their function appears to be to break up, by putrefactive processes, all dead organised matter, and thus prepare it for being again assimilated by plants, so as to form food for animals and for man; and it seems probable that they prepare the soil itself for plant growth by absorbing and fixing the nitrogen of the atmosphere. They are, in fact, omnipresent, and under normal conditions they are wholly beneficial. It is we ourselves who, by our crowded cities, our polluted streams, and our unnatural and unwholesome lives, enable them to exert their disease-creating powers.

A brief notice must also be given of two discoveries in practical physiology, which have perhaps done more to benefit mankind than those great mechanical inventions and philosophical theories which receive more general admira-

tion. These are: the use of anæsthetics in surgical operations, and the antiseptic treatment of wounds.

Anæsthetics were first used in dentistry in 1846, the agent being ether; while chloroform, for more severe surgical operations, was adopted in 1848; and though their primary effect is only to abolish pain, they get rid of so much nervous irritation as greatly to aid in the subsequent recovery. The use of anæsthetics thus renders it possible for many operations to be safely performed which, without it, would endanger life by mere shock to the system; while to the operating surgeon it gives confidence, and enables him to work more deliberately and carefully from the knowledge that the longer time occupied will not increase the suffering of the patient or render his recovery less probable. Nitrous-oxide gas is now chiefly used in dentistry or very short operations, sulphuric ether for those of moderate length, while chloroform is usually employed in all the more severe cases, since the patient can by its use be kept in a state of insensibility for an hour or even longer. There is, however, some danger in its use to persons with weak heart or of great nervous sensibility, and the patient in such cases may die from the effects of the anæsthetic alone.*

* The Hyderabad Chloroform Commission, which in 1889 thoroughly investigated the causes of death under chloroform, has proved that *all such deaths are preventible* if a different mode of administration is adopted; and its conclusions have been confirmed by the independent researches of four medical men—two English and two American physicians. Yet the old method of administration is still common in this country, no less than seventy-five deaths having occurred from this cause in 1896, while the Registrar-General records seventy-eight deaths from anæsthetics (almost all from chloroform) in 1895. There is thus a terrible amount of mortality due, apparently, to the ignorance of medical men on a subject as to which they are supposed to have exclusive knowledge. An excellent account of the work of the above-named Commission is given in the *Nineteenth Century* of March 1898 by a lady who has had to take chloroform more than once by both methods, and can, therefore, judge of their comparative effects by the best of tests—personal experience.

Even more important was the introduction of the antiseptic treatment in 1865, which, by preventing the suppuration of incised or wounded surfaces, has reduced the death rate for serious amputations from forty-five per cent. to twelve per cent., and has, besides, rendered possible numbers of operations which would have been certainly fatal under the old system. I remember my astonishment when, soon after the introduction of the practice, I was told by an eminent physiologist of the new method of performing operations, in which the freshly-cut surfaces could be left exposed to the air without dressings of any kind, and would soon heal. The antiseptic treatment was the logical outcome of the proof that suppuration of wounds and all processes of fermentation and putrefaction were not due to normal changes either in living or dead tissues but were produced by the growth and the rapid multiplication of minute organisms, especially of those low fungoid groups termed Bacteria. If, therefore, we can adopt measures to keep away or destroy these organisms and their germs, or in any way prevent their increase, injured living tissues will rapidly heal, while dead animal matter can be preserved unchanged almost indefinitely. In the case of wounds and surgical operations this is effected by means of a weak solution of corrosive sublimate, in which all instruments and everything that comes in contact with the wound are washed, and by filling the air around the part operated on with a copious spray of carbolic acid. Cold has a similar effect in preserving meat; while the process of tinning various kinds of food depends for its success on the same principle—of first killing all bacteria or other germs by heating the filled tins above the boiling point, and then keeping out fresh germs by air-tight fastening.

The combined use of anæsthetics and antiseptics has

almost robbed the surgeon's knife of its terrors, and has enabled the most deeply-seated organs to be laid open and operated upon with success. As a result, more lives are probably now saved by surgery than by any other branch of medicine, since, in the treatment of disease, there has been comparatively small progress except by trusting more to the healing powers of nature, aided by rest, warmth, pure air, wholesome food, and as few drugs as possible.

It is not generally known that surgery reached a high development in very early times, the Egyptians, the Indians, and the Greeks having attained great proficiency five hundred years before the Christian era. Hippocrates, about a century later, gives such a full account of the instruments and appliances, as well as the modes of operation in surgery, as to show that it was then an art of considerable antiquity and perfection. Trepanning, lithotomy, couching for cataract, and many other important operations, were successfully practised; hæmorrhage was arrested by cold, by compression, or by the use of styptics; while dislocations and fractures were treated almost as skilfully as in our own time. Owing, however, to the scanty knowledge of anatomy (due to the prejudice against dissecting the human body) amputations of the limbs were not attempted till a much later period; and till comparatively recent times the only means of stopping the flow of blood was by cauterising with a red-hot iron.

When we consider the danger of the more severe operations, even down to the middle of the nineteenth century, and the unsanitary conditions of life during the preceding centuries, which render it certain that blood-poisoning or gangrene must have been a very frequent result of all wounds, we can form some conception of the great amount of mortality and pain from which the antiseptic treatment has saved us. And in the operations themselves the

patients must have suffered increased agonies, due partly to the comparative rudeness of the instruments and appliances, and especially to the fact that when the knife was largely used cautery with the hot iron was the general mode of healing the wound. To those who lived amid the battles and slaughters and cruel punishments of the middle ages nothing would have seemed more incredible than that the most terrible wounds would some day be healed with little or no pain to the sufferer, while by the painless amputation of a limb innumerable lives would be saved. That this great boon has been conferred upon suffering humanity is certainly one of the most important triumphs of the nineteenth century.

CHAPTER XIX

THE NINETEENTH COMPARED WITH PRECEDING CENTURIES

"The long crude efforts of society
  In feeble light by feeble reason led,—
But gleaning, gathering still, effect of cause,
  Cause of effect, in ceaseless sequence fed,
Till, slow developing the eons through,
  The gibbering savage to a Darwin grew—
This hath Time witnessed! Shall his records now,
The goal attain'd—the end achieved, avow?"

J. H. DELL.

HAVING now completed our sketch of those practical discoveries and striking generalisations of science which have in so many respects changed the outward forms of our civilisation, and will ever render memorable the century which has just completed its course, we are in a position to sum up its achievements and compare them with what has gone before.

Taking first those inventions and practical applications of science which were perfectly new departures, and which have also so rapidly developed as to have profoundly affected many of our habits, and even our thoughts and our language, we find them to be fourteen in number.

1. Railways, which have revolutionised land travel and the distribution of commodities.

2. Steam Navigation, which has done the same thing for ocean travel, and has besides led to the entire reconstruction of the navies of the world.

3. Electric Telegraphs, which have produced an even greater revolution in the communication of thought.

4. The Telephone, which transmits, or rather reproduces, the voice of the speaker at a distance.

5. Friction Matches, which have revolutionised the modes of obtaining fire.

6. Gas Lighting, which enormously improved outdoor and other illumination.

7. Electric Lighting, another advance, now threatening to supersede gas.

8. Photography, an art which is to the external forms of nature what printing is to thought.

9. The Phonograph, which preserves and reproduces sounds as photography preserves and reproduces forms.

10. The Electric transmission of Power and Heat.

11. The Röntgen Rays, which render many opaque objects transparent, and open up a new world to photography and to science.

12. Spectrum Analysis, which so greatly extends our knowledge of the universe that by its assistance we are able to ascertain the relative heat and chemical constitution of the stars, and to prove the existence and measure the rate of motion of stellar bodies which are entirely invisible.

13. The use of Anæsthetics, rendering the most severe surgical operations painless.

14. The use of Antiseptics in surgical operations, which has still further extended the means of saving life.

Now, if we ask what inventions comparable with these were made during the previous (eighteenth) century, it seems at first doubtful whether there were any. But we may perhaps admit the development of the steam-engine from the rude but still useful machine of Newcomen to the powerful and economical engines of Boulton and Watt.

The principle, however, was known long before, and had been practically applied in the previous century by the Marquis of Worcester and by Savery; and the improvements made by Watt, though very important, had only a limited result. The engines made were almost wholly used in pumping the water out of deep mines, and the bulk of the population knew no more of them, nor derived any more direct benefit from them, than if they had not existed.

In the seventeenth century the one great and far-reaching invention was that of the telescope, which, in its immediate results of extending our knowledge of the universe, and giving possibilities of future knowledge not yet exhausted, may rank with spectrum analysis in our own era. The barometer and thermometer are minor discoveries.

In the sixteenth century we have no invention of the first rank, but in the fifteenth we have printing.

The mariner's compass was invented early in the fourteenth century, and was of great importance in rendering ocean navigation possible, and thus facilitating the discovery of America.

Then, backward to the dawn of history, or rather to prehistoric times, we have the two great engines of knowledge and discovery—the Indian or Arabic numerals, leading to arithmetic and algebra, and, more remote still, the invention of alphabetical writing.

Summing these up, we find only five inventions of the first rank in all preceding time—the telescope, the printing-press, the mariner's compass, Arabic numerals, and alphabetical writing, to which we may add the steam-engine and the barometer, making seven in all, as against thirteen in our single century.

Coming now to the theoretical discoveries of our time, which have extended our knowledge or widened our con-

ceptions of the universe, we find them to be about equal in number to the great practical inventions, as follows:—

1. The determination of the mechanical equivalent of heat, leading to the great principle of the Conservation of Energy.

2. The Molecular theory of gases.

3. The mode of direct measurement of the Velocity of Light, and the experimental proof of the Earth's Rotation. These are put together, because hardly sufficient alone.

4. The discovery of the function of Dust in nature.

5. The theory of definite and multiple proportions in Chemistry.

6. The Development of Electricity into the first rank among the Sciences.

7. The discovery of the real nature of Meteors and Comets, leading to the Meteoritic theory of the Universe.

8. The proof of the Glacial Epoch, its vast extent, and its effect upon the earth's surface.

9. The proof of the great Antiquity of Man.

10. The establishment of the theory of Organic Evolution.

11. The Cell theory and the Recapitulation theory in Embryology.

12. The Germ theory of the Zymotic diseases.

13. The discovery of the nature and function of the White Blood Corpuscles.

Turning to the past, in the eighteenth century we may perhaps claim two groups of discoveries:

1. The foundation of modern Chemistry by Black, Cavendish, Priestly, and Lavoisier; and

2. The foundation of Electrical science by Franklin, Galvani, and Volta.

The seventeenth century is richer in epoch-making discoveries, since we have:—

3. The theory of Gravitation established.

4. The discovery of Kepler's Laws.

5. The invention of Fluxions and the Differential Calculus.

6. Harvey's proof of the Circulation of the Blood, but this can hardly be classed as a discovery of the first rank.

7. Roemer's proof of the finite Velocity of Light by Jupiter's satellites.

Then, going backward, we can find nothing of the first rank except Euclid's wonderful system of geometry, derived from earlier Greek and Egyptian sources, and perhaps the most remarkable mental product of the earliest civilisations; to which we may add the introduction of Arabic numerals and the use of the alphabet. Thus in all past history we find only nine or ten important theoretical discoveries antecedent to the nineteenth century as compared with thirteen during that century. It will be well now to give comparative lists of the great inventions and discoveries of the two eras, adding a few others to those above enumerated.

Of the Nineteenth Century	*Of all Preceding Ages*
1. Railways.	1. The Mariner's Compass.
2. Steam Ships.	2. The Steam Engine.
3. Electric Telegraphs.	3. The Telescope.
4. The Telephone.	4. The Barometer and Thermometer.
5. Lucifer Matches.	5. Printing.
6. Gas Illumination.	6. Arabic Numerals.
7. Electric Lighting.	7. Alphabetical Writing.
8. Photography.	8. Modern Chemistry founded.
9. The Phonograph.	9. Electric Science founded.
10. Electric Transmission of Power.	10. Gravitation established.
11. Röntgen Rays.	11. Kepler's Laws.
12. Spectrum Analysis.	12. The Differential Calculus.
13. Anæsthetics.	13. The Circulation of the Blood demonstrated.
14. Antiseptic Surgery.	

15. Conservation of Energy.
16. Molecular Theory of Gases.
17. Velocity of Light directly measured, and Earth's Rotation experimentally shown.
18. The uses of Dust.
19. Electricity made a great Science.
20. Chemistry, definite proportions.
21. Meteors and the Meteoritic Theory.
22. The Glacial Epoch.
23. The Antiquity of Man.
24. Organic Evolutions established.
25. Cell Theory and Embryology.
26. Germ theory of disease, and the function of the Leucocytes.

14. Light proved to have Finite Velocity.
15. The development of Geometry.

Of course these numbers are not absolute: either series may be increased or diminished by taking account of other discoveries as of equal importance, or by striking out some which may be considered as below the grade of an important or epoch-making step in science or civilisation; but the difference between the two lists is so large that probably no competent judge would bring them to an equality. Again, it is noteworthy that nothing like a regular gradation is perceptible during the last three or four centuries. The eighteenth century, instead of showing some approximation to the wealth of discovery in our own age, is less remarkable than the seventeenth, having only about half the number of really great advances.

It appears, then, that the statement in my first chapter, that to get any adequate comparison with the nineteenth

century we must take, not any preceding century nor group of centuries, but rather the whole preceding epoch of human history, is justified, and more than justified, by the comparative lists now given. And if we take into consideration the change effected in science, in the arts, in all the possibilities of human intercourse, and in the extension of our knowledge, both of our earth and of the whole visible universe, the difference shown by the mere numbers of these advances will have to be considerably increased on account of the marvellous character and vast possibilities of further development of many of our recent discoveries. Both as regards the number and the quality of its onward advances, the age in which we have lived fully merits the title I have ventured to give it of—THE WONDERFUL CENTURY.

Part II—Failures

What shalt thou do to be for ever known?
Poet or statesman—look with steadfast gaze,
And see yon giant Shadow 'mid the haze,
Far off but coming. Listen to the Moan
That sinks and swells in fitful undertone,
And lend it words, and give the shadow form;
And see the Light, now pale and dimly shown,
That yet shall beam resplendent after storm.
Preach thou their coming, if thy soul aspire
To be the foremost in the ranks of fame;
Prepare the way, with hand that will not tire,
And tongue unfaltering, and o'er earth proclaim
The Shadow, the Roused Multitude;—the Cry,
"Justice for All!"—the Light, True Liberty.

CHARLES MACKAY.

CHAPTER XX

THE NEGLECT OF PHRENOLOGY

"All be turned to barnacles, or to apes
With foreheads villainous low."

SHAKESPEARE.

"His searching wisdom taught
How the high dome of thought
Pictured the mind;
On that fair chart confest,
Traced he each reckless guest
Which in the human breast
Lies deep enshrined."

Eulogy of Dr Gall.

In the preceding chapters I have, to the best of my ability, given a short, but I trust accurate, sketch of the most prominent examples of material and intellectual progress during the nineteenth century. In doing this I have fully recognised the marvellous character of many of these discoveries, as well as the great amount and striking novelty of the material advances to which they have given rise. But, along with this continuous progress in science, in the arts, and in wealth-production—which has dazzled our imaginations to such an extent that we can hardly admit the possibility of any serious evils having accompanied or been caused by it—there have been many serious failures: intellectual, social, and moral. Some of our great thinkers have been so impressed by the terrible nature of these failures that they have doubted whether the final result of the work of the century has any balance of good over evil—of happiness over misery—for mankind at large. But

although this may be an exaggerated and pessimistic view, there can be no doubt of the magnitude of the evils that have grown up or persisted in the midst of all our triumphs over natural forces and our unprecedented growth in wealth and luxury.

We have also neglected or rejected some important lines of investigation affecting our own intellectual and spiritual nature, and have, in consequence, made serious mistakes in our modes of education, in our treatment of mental and physical disease, and in our dealings with criminals. A sketch of some of these failures will now be given, and will, I believe, constitute not the least important portion of my work. I begin with the subject of phrenology, a science of whose substantial truth and vast importance I have no more doubt than I have of the value and importance of any of the great intellectual advances already recorded.

In the last years of the eighteenth century Dr François Joseph Gall, a German physician, discovered (or rediscovered) the facts, now universally admitted, that the brain is the organ of the mind, that different parts of the brain are connected with different mental and physical manifestations, and that, other things being equal, size of the brain and of its various parts is an indication of mental power. He began his observations on this subject when a boy, by noticing the different characters and talents of his schoolfellows—some were peaceable, some quarrelsome; some were expert in penmanship, others in arithmetic; some could learn by rote even without comprehension, while others, although more intelligent, could not do so. He himself was one of the latter group; and this led him to notice that those who surpassed him most in this power of verbal memory, however different they might be in other respects, had all prominent eyes. The

meaning of this peculiarity he did not at the time perceive, but he continued his observations at college and in the hospitals, and very gradually acquired the certainty that strongly marked peculiarities of character or talent were associated with constant peculiarities in the form of the head. This led him to pay special attention to the anatomy of the brain and its bony covering; he made collections of skulls and casts of skulls of persons having special mental characteristics; he collected, also, the skulls of various animals and compared their brains with those of man; he visited prisons, schools, and colleges, everywhere making observations and comparisons of form and size with mental faculties; and, later on, when he became physician to a lunatic asylum in Vienna, he had vast opportunities for studying the diseased brain and for observing the correspondence between the form of the head and the special delusions of each patient.

It was after more than twenty years of continuous observation and study, under exceptionally favourable conditions, that he became convinced that he had discovered a real connection between the mental faculties and the form and size of the various parts of the brain; and in the year 1796 he began lecturing on the subject. His lectures were continued for five years, and were attended by numerous physicians and medical students, as well as by men of culture of all ranks, many converts being made. The lectures were then forbidden by the authorities, on the ground that he had not had permission to deliver them. He declined to ask for permission, and soon afterwards left Vienna, and with his most distinguished pupil, Dr Spurzheim, travelled through a large part of Northern Europe, lecturing in the chief cities, and finally settled in Paris in 1807. In 1813 Spurzheim visited Great Britain, where he lectured for four years; and it was during this

period that George Combe made his acquaintance in Edinburgh, and thenceforth began that long course of personal observation and study which rendered him the best English exponent of the science, and probably one of the best practical phrenologists of any country.

Combe was a man of great mental power, extremely logical, ardent in the pursuit of truth, but also extremely cautious in ascertaining what was and what was not true. A clever writer in the *Edinburgh Review*—Dr John Gordon—had just condemned and ridiculed the doctrines of Gall and Spurzheim as being full of absurdities and misstatements and "a piece of thorough quackery from beginning to end." It was a clever and vigorous critique, apparently founded on knowledge; and Combe read it with so much enjoyment and conviction that, when shortly afterwards Spurzheim came to Edinburgh and gave a course of lectures, he refused to go and hear him. When the lectures were over, however, a friend asked Combe if he would like to come to his house and see Dr Spurzheim dissect a brain; and, as he was always eager for knowledge and had already studied anatomy, he went. Combe had been a physiological student under Dr Barclay, and had often seen him dissect the brain, but was taught nothing of its functions, of which the lecturer had declared that nothing was known. But when Dr Spurzheim dissected, Combe tells us that he at once saw how "inexpressibly superior" was his method in showing its detailed structure; while he saw at the same time that the reviewer had displayed profound ignorance and had been guilty of gross misrepresentation. He therefore attended Spurzheim's second course of lectures, and was so impressed that he determined to observe and study for himself. He at once ordered from London a collection of casts of the skulls of men of known mental peculiarities — artists, writers,

workers, criminals, etc.; but when they arrived the differences looked so slight that he thought he should never be able to determine the peculiarities which, on Dr Spurzheim's theory, were so important, and therefore determined to put them aside and trouble no more about them. But their arrival was known to some of his friends, and numbers of persons called, asking to see them, and begging him to explain their phrenological peculiarities. He was thus *forced* to observe them more carefully; and as he showed them to each fresh visitor he began to see that there were large differences between them, and that these differences corresponded to the differences of their known characters according to the position of the organs as determined by Gall and Spurzheim. He thus obtained confidence in his powers of observation, and therefore determined to go on with the study. He began to observe the heads of all his friends and clients, and found that these usually confirmed the experience already gained. This gave him confidence; and for three years he went on studying both the heads of living persons and actual crania, the latter more especially, in order to learn the exact amount of correspondence or difference between the outer and inner surfaces of the skull. His visitors increased as his knowledge rendered his explanations more interesting, and thus, he tells us, he became a phrenologist and a lecturer on phrenology by a concatenation of circumstances which were not foreseen and the ultimate consequences of which he had never contemplated.

Before proceeding further with a sketch of the evidences for phrenology it is well to consider briefly what sort of man Combe was. At the period just referred to he was twenty-seven years old, and in good practice in Edinburgh as a lawyer. He carried on his profession for twenty years longer, his practice continually increasing, notwith-

standing his various other occupations and the unpopularity of many of his writings. During this time he had written and published several works—some very extensive—on "Phrenology"; "The Constitution of Man"—a work which in Scotland caused him to be considered an infidel, but which in England had a circulation of a hundred thousand; "Lectures on Popular Education"; "Lectures on Moral Philosophy," afterwards enlarged into a work which went through several editions, besides numerous articles in periodicals and newspapers on a variety of subjects. Though brought up in a religious Scottish family, and of a highly reverential nature, he entirely emancipated himself from religious dogmas, and became the best exponent of a well-reasoned system of natural religion. He was one of the earliest educational reformers, and may almost be considered as the founder of rational systems of education in this country. Wherever he went—and he visited repeatedly many European countries as well as the United States—his great reputation as a religious, social, and educational reformer and philosophical thinker led to his being welcomed in the best social, scientific, and political circles. At home he was consulted by many persons of eminence, including the Prince Consort, on the best system of education for their children. Sir James Clark, Richard Cobden, Robert Chambers, and Charles Mackay the poet were among his intimate friends; while Lord John Russell and other influential politicians were glad to receive information from him on all subjects connected with improved systems of education.

It may be truly said that on every subject on which he wrote—the constitution of man, natural religion, education, criminal legislation, the lunacy laws, the currency question, moral philosophy—he was far in advance of his age; and almost all his principles and his proposals on these subjects,

though considered heretical or impracticable by most of his contemporaries, are now either actually adopted or admitted to be correct both in philosophy and in practice. But the one subject to which he gave more careful study than to any other, phrenology—which was indeed the very foundation on which his philosophy and his educational theories were built—was contemptuously rejected by the great bulk of the scientific and literary men of his time, without adequate examination, without any reasonable study of so complex and important a subject, but almost entirely on false assumptions, gross misrepresentations, or *a priori* reasoning. All who have given any careful consideration to the writings of Dr Gall and George Combe admit that both were men of exceptional mental power careful observers, close reasoners, cautious in arriving at conclusions on anything less than overwhelming evidence. The first gave all his energies, during a long life, to the establishment, on a firm basis of observation and experiment, of the new science of phrenology which he had founded; the second, coming to the subject with prepossessions against it, took nothing for granted, observed every alleged fact for himself, criticised, modified, and extended the work of his teachers, and taught it by lectures and books in a manner at once popular and scientifically exact. And the life-work of two such men was disposed of, not by pointing out important errors of observation or of reasoning, but largely by abuse, or by means of trivial objections which the most rudimentary knowledge shows to be unfounded.

Let us now consider, briefly, what phrenology is, what is the evidence on which it is founded, and what are its practical results. In the first place, it is a purely inductive science, founded, step by step, on the observation and com-

parison of facts, confirmed and checked in every conceivable way, and subjected to the most rigid tests. By means of large collections of skulls, and casts of the heads of men and women remarkable for any mental faculty or propensity, and by observations and measurements of thousands of living persons, the correspondence of form with function was first suspected, then confirmed, and finally demonstrated by the comparison of the heads of individuals of every age, both in health and disease, and under the most varied conditions of education and environment. Three men of exceptional talents and acuteness of observation devoted their lives to the collection of these facts. They studied also the brain itself, and discovered many details of its structure before unknown. They studied the skull, its varying thicknesses in different parts and at different ages, as well as under the influence of disease; and it was only after making allowance for every source of uncertainty or error that they announced the possibility of determining character with a considerable amount of certainty, and often with marvellous exactness. Surely this was a scientific mode of procedure, and the only sound method of ascertaining the relations that exist between the development of the brain and the mental faculties and powers. A few examples, showing how far this was actually done, will now be given.

In October 1835 Combe visited the Newcastle Lunatic Asylum and examined the heads of several of the patients. These were selected by the Surgeon-Superintendent, Mr Mackintosh, and their mental peculiarities had been noted down by him beforehand. For convenience of comparison, Combe's notes and those of Mr Mackintosh are put in parallel columns.*

* These tests at Newcastle are fully reported in the *Phrenological Journal*, vol. ix. pp. 519-526.

Combe's Phrenological Notes	*Superintendent's Notes*
PATIENT J. N.	
ANIMAL organs large.	A bad character.
CAUTIOUSNESS and DESTRUCTIVENESS predominant.	Hypochondriacal.
HOPE small. MORAL FACULTIES deficient.	Suicidal.
PATIENT L. J.	
ACQUISITIVENESS enormously large.	Monomania, wealth.
PATIENT J. M.	
Intellectual organs well developed.	Generally sane and tractable.
VENERATION, CONCENTRATIVENESS *very* large.	Monomania, the Messiah.
FIRMNESS, SELF-ESTEEM large.	A proselyte Jew; will lead the Jews to the conquest of England.
PATIENT C. S.	
Intellectual organs large.	
Organ of NUMBER *exceedingly* large.	Dementia — perpetually employed with figures and arithmetic.
FEMALE PATIENT M. D.	
Moral faculties deficient.	
HOPE extremely small.	Great misery.
DESTRUCTIVENESS and CAUTIOUSNESS excessively large.	Suicidal monomania.

At the Dunstane Lodge Asylum, near Newcastle, Mr Combe, attended by two surgeons, the editor of the *Tyne Mercury*, and a few other gentlemen, examined the heads of a few patients submitted to him by the proprietor, Mr Wilkinson, who appended his own remarks on the nature of their insanity.

Mr Combe's Delineation	*Mr Wilkinson's Remarks*
PATIENT J. F.	
SELF-ESTEEM and FIRMNESS very large. WONDER, SECRETIVENESS, and ACQUISITIVENESS also large. The character of the insanity will be self-esteem, and probably cunning and theft.	He proclaims himself to be the Great God, and entertains a high esteem of his person and strength. He pilfers and picks up little articles whenever he can lay his hands on them.
PATIENT R. M.	
Intellectual organs large. IMITATION very large. COMBATIVENESS and DESTRUCTIVENESS very large. HOPE and CONSCIENTIOUSNESS deficient. Character very violent; probably attempted suicide; great power of expressing his feelings by his countenance and gestures.	He has a talent for all kinds of mechanical work. He is extremely violent, and has a great talent for imitation. His countenance is fearfully expressive when he is excited.
PATIENT H. C.	
Large COMBATIVENESS, enormous SELF-ESTEEM. FIRMNESS and PHILOPROGENITIVENESS large. Intellect and IMITATION large. He will manifest extreme conceit with great determination. He will have a great talent for imitation and strong powers ot natural language.	This exactly describes the character. He believes himself to be a king; he is prone to imitate; he is opinionative, and fond of children.

On 28th October in the same year Mr Combe visited the Newcastle Gaol, accompanied by several medical gentlemen and others who had attended his lectures. Several of the criminals were examined by him, and while he was writing down their characteristics, Dr George Fife, the assistant-

surgeon to the gaol, who knew nothing of phrenology, wrote a brief account of their characters from his personal knowledge. The following are the three cases submitted :—

Mr Combe	*Dr Fife*
P. S. (aged 20)	
My inference is that this boy is not accused of *violence*; he has a talent for deception and a desire for property not regulated by justice. It is most probable that he has *swindled*: he has the combination which contributes to the talent of an *actor*.	Twice convicted of theft. He has never shown *brutality*, but he has no sense of honesty. He has frequently attempted to *impose* on Dr Fife. . . . He has a talent for *imitation*.
T. S. (aged 18)	
This boy is very different from the last. He has probably been committed for assault connected with women. He may have stolen, though I think this less probable. He has fair intellectual talent, and is *improvable*.	Crime, rape. . . . Mild disposition; has never shown actual vice.
J. W. (aged 73)	
Case for a lunatic asylum rather than a gaol. Moral organs *very* defective. Intellect moderate. Cautiousness very large. No control of the lower propensities.	A thief; obstinate, ungrateful; one of the most depraved characters.

Another interesting test case is the following :—A surgeon at Chatham sent a skull to Dr Elliotson, stating that he belonged to a literary society the members of which were much divided on the subject of phrenology, and it was suggested that the skull in question, being that of a person whose character and previous history was known to the

members, should be sent to some eminent phrenologist with a request for a delineation of the character. Dr Elliotson, to whom the person who sent the skull was quite unknown, gave him the following sketch of the character of the deceased person:—

"I should say that he was a man of strong passions, which overbalanced his intellect; that he was prone to *great violence*, but *by no means courageous*; that he was *extremely cautious and sly*; his sexual desires were strong, but *his love of offspring very remarkable.* I can discover no good quality about him except the love of his children, if he had any. The most striking *intellectual* quality in him, I should think, was his *wit.* He might also have been a good *mimic.*"

The actual history and character of the man are given at length, but the following are the main points:—He was of respectable parentage, but was sensual and vicious. He became a farmer in Cheshire, and took to *smuggling salt*, which was then contraband; but he always escaped detection, though long suspected. Later, he made use of his assistants in the smuggling business for the purpose of robbing the farmers around of corn, which, being a farmer, he was able to sell *without suspicion.* He was at length detected and condemned to death, a sentence which was commuted to transportation for life. He was, however, on account of his age, not sent abroad, but kept in the convict hulks. After two years, being in very bad health, he was transferred to the hospital ship, where he remained till his death. Here he was very reserved as to his own history, but, being treated with great kindness, he made statements to the following effect:—(1) That though he had led a lawless life he had never committed murder. (2) That he had a wife and eight children, a natural son in Wales, and that he had several mistresses

in different parts of the country up to the time of his apprehension.

In the hospital he exhibited a severe *sarcastic wit* at the expense of those around him. The manners and language of the clergyman at the hospital were the frequent subjects of *his mimicry*. He exhibited a strong *attachment to his children*, and frequently spoke of them in the most affectionate manner.

It will be observed that *all* the special features of the man's character, as given by Dr Elliotson, were strictly correct, although the combination was an uncommon and remarkable one; and every unprejudiced person will agree with the following resolution, which was passed by the Society unanimously, and transmitted to Dr Elliotson:—

"That the character given of L. by Dr Elliotson, from the inspection of the skull, corresponds so exactly with his history that it is impossible to consider the coincidence as the effect of chance, but that it is an instance which, if supported by many others, affords a strong foundation for the truth of phrenology." *

One other test of a remarkable character is given in the same volume as that containing the above (p. 467). In the spring of 1826 Dr Thomson, a navy surgeon, had charge of 148 convicts on the voyage to New South Wales. A friend of the doctor's induced him to allow a phrenologist, Mr De Ville, to make an examination of the whole number, giving the surgeon a memorandum, which he might compare with the actual character of the men during the long voyage. This was done; and one man in particular was noted as being "very dangerous from his energy, ferocity, and talent for plots and profound dissimulations." The voyage occupied four months, and the surgeon kept a

* The above experiment, with correspondence, is given in full in the *Phrenological Journal*, vol. iv. p. 258.

careful official journal as regards the convicts, the main facts of which are summarised in the following letter to his friend, dated Sydney, 9th October 1826:—

"I have to thank you for your introduction to De Ville and to phrenology, which I am now convinced has a foundation in truth, and beg you will be kind enough to call on Dr Burnett, whom I have requested to show you my Journal, at the end of which is Mr De Ville's report, and my report of conduct during the voyage. . . . *De Ville is right in every case except one*—Thomas Jones; but this man can neither read nor write, and, being a sailor, he was induced to join the conspiracy to rise and seize the ship and carry her to South America, being informed by Hughes, the ringleader, that he would then get his liberty. Observe how De Ville has hit the real character of Hughes, and I will be grateful to De Ville all my life; for his report enabled me to shut up in close custody the malcontents and arrive here not a head *minus*, which, without the report, it is more than probable I should have been. All the authorities here have become phrenologists, and I cannot get my Journals out of their offices until they have perused and reperused De Ville's report." *

One more case only can here be given. Combe reviewed a volume by Archbishop Whately, which led to some correspondence, and the Archbishop sent Combe a cast of his head, asking for his unbiassed opinion. The Archbishop was much struck by the character sketch sent, but wishing for a more complete test, requested Combe to send the cast to some other phrenologist, *without any indication of the person it represented*, and let him know the result. Combe did so, and the resulting report was shown to two of the Archbishop's most intimate friends, who expressed their wonder at the accuracy with which the character had been unfolded,

* See *Phrenological Journal*, vol. iv. p. 467.

declaring that, except in a few minor details, they could find nothing to correct. The same cast was then sent to a third phrenologist, and the Archbishop gave the following personal details in reference to the two last :—" What I was most struck with was, in the one, my difficulty of withstanding solicitations; in the other, my delight in an infant school. The former, though well known to myself, was, I believe, never detected in my conduct."

I will now briefly state my own experiences of phrenological delineation, the accuracy of which confirmed me in the belief that the science is a true and important one, which I had already reached by a study of the works of George and Andrew Combe. When I was about three or four-and-twenty, living at Neath, Glamorganshire, I had my head examined by two phrenological lecturers who visited the town at different times. As the fee for a full delineation was rather high I only received a sketch, and many details were therefore omitted. But all that was stated was correct, and much of it remarkably so, as shown by the following extracts :—

1. " You will pay great attention to facts, but so soon as facts are presented you will begin to reason and theorise upon them. You will be constantly searching for causes." 2. " You will be a good calculator, will excel in mathematics, and will be very systematic in your arrangements." 3. " You possess a good deal of firmness in what you conceive to be right, but you want self-confidence."

These are the main points of the least full and least successful delineation, and the only error is that my mathematics are strictly *limited*, as indicated in the better delineation, from which I extract the following :—

4. " This gentleman should learn easily and remember well, notwithstanding *verbal* memory is but moderate." 5. " He has some vanity but more ambition. He may

occasionally exhibit a want of *self-confidence*; but general opinion ascribes to him too much. In this opinion is wrong. *He* knows that he has not enough." 6. "If *Wit* were larger he would be a good mathematician, but, without it, I do not put his mathematical abilities at first-rate." 7. "He has some love for music from his *Ideality*, but I do not find a good ear or sufficient *Time*." 8. "He is fond of argument, and not easily convinced."

Nos. 1 and 8, combined with large *Ideality* and *Wonder* (as indicated by both phrenologists), giving a strong love of the beauties and the mysteries of nature, furnish the explanation of my whole scientific work and writings.

Nos. 2 and 6 are exceedingly suggestive on account of their curiously precise estimate of faculty. At school I was good at arithmetic and elementary algebra, which always had a fascination for me; but as I left school when only fourteen I did not advance far. After I came of age, however, I was for two years English and drawing master in the Collegiate School at Leicester, the head master of which was a high Cambridge wrangler, and he kindly offered to assist me in the higher mathematics. I worked through "Hind's Equations" and "Trigonometry" successfully, got on with the "Differential Calculus" with some difficulty, but broke down over the "Integral Calculus" for want of that faculty of intuitively perceiving resemblances and incongruities, whether in ideas, words, or symbols, somewhat awkwardly termed by phrenologists "wit," but defined by some as the "organ of analogy." As a fact, I have no power to joke or make a pun or see quickly all the possibilities of a position in chess, though no one more enjoys these diversions than myself. Most great mathematicians are either witty or poetical — Rankine, Clifford, De Morgan, Clerk-Maxwell, "Lewis Carroll," and Sylvester being well-known examples; and that a

phrenologist should detect my failure in the higher mathematics, and connect it with the deficiency of this organ, has always seemed to me very remarkable.

Nos. 3 and 5 both dwell on my want of self-confidence, and the second says that I am often thought to have too much. This is very true. In youth I was painfully shy, and was literally *afraid* of calling on people without an invitation. When I was in Paris, in 1848, I was accused of being too proud to call on people, and suffered much in consequence; and throughout my whole life I have never been able to become intimate with any persons except those whose manners and dispositions were such as to make me at once feel sympathetic and at home with them. I have, therefore, made fewer intimate friends than most men, and all for want of a larger development of self-esteem.

No. 4 indicates my deficiency of verbal memory, due to a small organ of language. This makes the acquiring of foreign languages painful to me, and interferes with my success as a public speaker; since, though I know what ideas or arguments I wish to advance, I cannot at once find the right words by which to express them adequately, and in the effort to find the words the connection of ideas is liable to be lost.

Lastly, No. 7 states the exact nature of my mind in relation to music. Grand or pathetic music affects me strongly; but I should not detect considerable errors in the performance, my ear, as it is termed, being exceedingly deficient, while my perception of time is only a trifle better.

There are some other estimates as to my innermost nature which I know to be correct, but which are not suitable for exposition here; and these, combined with the more obvious characteristics above enumerated, produced a strong impression on my own mind as to the

value of phrenology, which has remained unimpaired throughout my life.

The evidence of the value of phrenology in determining the hidden springs of character here given might be increased ten or twenty-fold from the records of the early part of the century; and they produced an effect on the public mind which has not yet disappeared, since it is not an uncommon thing to meet with people who are quite unaware that the phrenology of their youth has been wholly rejected by the scientific world of to-day. Let us, therefore, now briefly consider how and why it was so rejected.

Why Phrenology was rejected

The first great objection was a religious one. The orthodox clergy, both in Scotland and England, held it to be contrary to Scripture and dangerous to morality. These objectors, of course, never made any pretence of studying the subject or even of ascertaining what it really was. They decided at once that it was irreligious, and their flocks, for the most part, followed them.

The next body of opponents was that of the metaphysicians, headed by the great name of Sir William Hamilton. These philosophers, as they termed themselves, had, from the earliest ages, studied the mind by observations on their own consciousness and on the mental operations of others so far as they could detect them. They recognised no connection between the mind and the organism; and as the phrenologists maintained that they had not only proved such a connection but had also determined the particular parts of the brain which were the organs of the separate faculties—many of which the metaphysicians did not recognise at all—they, of course, declared the whole

science to be erroneous and its teachers to be little better than deluded fanatics. These objectors, also, never condescended to make any personal study of the science, and remained quite ignorant of its facts or of the mass of evidence which had been collected in support of it.

The third class of opponents consisted mainly of doctors and physiologists. At first, large numbers of these were converted by attending the lectures of Gall, Spurzheim, and Combe. In fact there is, so far as I can find, no record of any medical men or others who, having first attended a complete course of lectures, then proceeded to apply and test the information they had obtained with an earnest desire to ascertain the truth of the matter who did not become confirmed phrenologists. Down to about the years 1840 or 1845 phrenology continued to progress, and then there seemed to be no reason why it should not take its place among the recognised sciences, since it was acknowledged by such men as Sir James Clarke, Physician to the Queen; Sir John Forbes, M.D.; Dr Elliotson; Dr William Gregory; Dr Engledue; Dr Conolly, Physician of Hanwell Asylum; Dr Abernethy, Professor of Anatomy and Surgery to the College of Surgeons, and many others. Soon after this period, however, it began to decline; and as the causes which led to this decline have, I believe, never been clearly pointed out, I will here state them as they seem to me to have acted.

The two main causes which discredited phrenology appear to have been (1) the increase of itinerant lecturers, many of whom were uneducated, and some ignorant of the subject they professed to expound; and (2) its association with mesmerism or hypnotism, which, at that time, was still more virulently opposed.

1. Although phrenology, to be thoroughly understood

and applied to the accurate delineation of character, requires a considerable amount of study and long practice, yet it appears, superficially, to be very easy; and it can actually be applied in cases of very marked character with fair success after a moderate amount of practice. Hence although many of the public exponents of the science were very able men, there were others who adopted the business of lecturer and examiner of heads with imperfect knowledge. These, by their ignorance of the anatomy and physiology of the brain, their clumsiness in detecting the comparative size of the organs, and their inability to estimate the complicated results produced by the various combinations of the organs as influenced by temperament, education, and social position, were liable by their mistakes to bring great discredit on the subject, since the public, and especially those who opposed phrenology from any of the causes already stated, could not, or would not, distinguish between the student and the pretender, and loudly proclaimed that these failures demonstrated the fallacy of the whole science. Considering all these sources of opposition and disrepute, and the difficulty of moving the established sciences and professions, or the official world, to recognise any new thing, it is not to be wondered at that when the enthusiasm of the early investigators and discoverers had passed away, no new students were found of sufficient independence, ability, and position to take their place.

2. Just about the time when phrenology was gaining a wide acceptance, painless operations during the mesmeric trance were exciting the fiercest opposition of the medical profession; and Dr John Elliotson, President of the Medical and Chirurgical Society, Lecturer at St Thomas' Hospital, and a professor at the University of London—an ardent phrenologist and founder of the Phrenological

Association — was the chief defender of these painless operations, for supporting and practising which his professorship was taken from him. As regards this question of hypnotism: Dr Elliotson is now known to have been right, and his opponents and traducers wholly wrong and grossly prejudiced, as will be shown in our next chapter; yet this prejudice undoubtedly reacted upon phrenology, and, together with the theological and metaphysical prejudice and that caused by imperfectly educated lecturers and professors, checked the official recognition it might otherwise have received, and rendered it impossible for students of medicine to become avowed phrenologists without injury to their professional prospects.

These combined influences led to its being treated as altogether a fallacy; and so complete became the ignorance of it among physiologists and medical men in the latter half of the century that it was, and is, often spoken of as a purely fantastic scheme, the product of the *imaginations* of its founders, and as being unsupported by observation and experiment. The complete ignorance of *how* phrenology was discovered by Gall, and of the enormous body of carefully observed facts and experiments it was founded upon, is well shown by the absurdly trivial nature of the objections made to it, even by men who might be supposed at least to have read some of the works of its founders before rejecting it. The most common and often-repeated objection is that of the frontal sinuses and the varying thickness of the skull in different parts and in different individuals, which are adduced as if they were known only to the objectors, and as if the eminent anatomist who devoted thirty years to the study of the brain and its bony covering had remained quite ignorant of them! If the objectors had read any work upon phrenology they would have found that this was one of the

very earliest of the small difficulties which the phrenologists recognised and overcame, and which every student learns how to allow for; while, if it were a much greater difficulty than it is, it could only affect the practical application of phrenology in certain cases and to a limited extent without in any way disturbing its general principles or the vast body of facts on which it is founded. Even so eminent a physiologist and so careful a thinker as the late Professor Huxley, when I once asked him *why* he did not accept phrenology as a science, replied at once: "Because, owing to the varying thickness of the skull, the form of the outside does not correspond to that of the brain itself, and therefore the comparative development of different parts of the brain cannot be determined by the form of the skull." To this I replied that the thickness of the skull varied at most by a few *tenths* of an inch, whereas the variations in the dimensions and the form of the head as measured in different diameters varied by whole *inches*, so that the size and proportions of the head as measured or estimated by phrenologists were very slightly affected by the different thickness of the skull, which, besides, had been carefully studied by phrenologists as dependent on temperament, age, etc., and could in many cases be estimated. He admitted the correctness of this statement, and had really no other objection to make, except by saying that he always understood it had been rejected after full examination (which it certainly had not been), and to ask, if it were true, why was it not taught by any man of scientific reputation? The case of Dr Elliotson, however, showed that a man of high scientific reputation risked not only his reputation but his means of living if he taught unpopular truths; while another man of scientific reputation, the late H. C. Watson—the well-known botanist—not only taught it for many years, as editor of the *Phrenological*

Journal, but held to its doctrines, as I know from personal correspondence, to the end of his life.

Almost the only other serious objection is to the detailed classification of the mental faculties and to the names given to the several organs. But such objections exist even in the best established sciences, such as geology, where both classification and nomenclature are continually changing in the effort to approach nearer to the facts of nature. Phrenology is a science of observation as truly as is geology itself; it is a highly complex and difficult study, and it can hardly be supposed that the half-dozen eminent men who established it have exhausted its possibilities. The classification, or rather the enumeration, of the mental faculties, whose function has been found to be dependent on certain brain areas, is wholly founded on long-continued observation and comparison; and there is, of course, room for improvement, founded on further observations. But in this case the objections of those who classify the mental faculties from their own consciousness are of no avail. Our consciousness does not reveal the brain organs on which the faculties depend, and cannot therefore be used to criticise phrenology, which is the science of this dependence. And in like manner the older anatomists, who only *dissected* the brain, had no valid grounds of objection, since, as Combe always urged, " dissection never reveals functions."

But while rejecting phrenology, neither anatomists, physiologists, nor anthropologists were able to give us any knowledge of the relations of mind and brain by other means. Enormous collections of skulls were formed; they were figured and accurately measured, were classified as brachycephalic or dolichocephalic, and in various other ways, but nothing came of it all, except a rough determination of the average size and typical form of skull of the different races of man, with no attempt, whatever, to connect

this typical form with the mental peculiarities of the several races. Never, perhaps, was so much laborious scientific work productive of so inadequate a result.

Ferrier's Localisation of Functions

But about the year 1870 several Continental physiologists, and in this country, Professor Ferrier, began to experiment on the brains of living animals, which were excited by weak galvanic currents applied to the exposed surface at different spots, and the resulting visible effects observed. In this way it was found that the excitement of certain limited areas caused the contraction of definite sets of muscles, leading to motion of the limbs, body, face, or head of the animal. This was termed the Localisation of Functions of the Brain, and was at once adduced by popular writers as giving the final death-blow to phrenology, since it showed (as they ignorantly assumed) that portions of the brain which the phrenologists had alleged to be the organs of purely mental faculties were really only organs of muscular movements. Such writers entirely overlooked the very obvious considerations that the brain may be—in fact, must be—the centre for the production of movements as well as for initiating ideas; and that the rude method of exciting the living brain by galvanism was not likely to develop the purely mental phenomena, which, indeed, in the animals experimented on, could only be exhibited *through* muscular movements. Again, it is quite possible, and even probable, that, while the cortex or grey matter on the surface of the brain is the seat of ideation, the more deeply-seated matter may contain the centres for muscular and nervous action, and may be the part which is excited by the galvanic current. But this very fact of the connection of certain definite brain areas

with muscular motion is no new discovery, as modern writers seem to suppose, but was known to Dr Gall himself, although he did not possess the modern appliances for the full experimental demonstration of it. In one of his first writings upon his discoveries—his letter to Baron de Retzer upon the Functions of the Brain in Man and Animals—he stated that there was a strange communication of the muscles with cerebral organs, adding, "when certain cerebral organs are put in action you are led, according to their seat, to take certain positions, as though you are drawn by a wire, so that one can discover the seat of the acting organs by the motions." This is the natural "expression of the emotions" which was so well studied by Darwin, but which Gall at the end of the last century had already determined to have its seat in the same parts of the brain which originated the motions themselves. And these facts were well known to all the early students of phrenology. Dr Davey of Bristol stated to the "Bath and Bristol Medical Association" in 1874 that, in 1842, he was present at a series of experiments which went to demonstrate, in the most decided and unequivocal manner, that the stimulation of many parts of the cerebrum of man did excite both sensation and motion. He added: "I affirm that, twenty-eight years before Hitzig ascertained and taught the fact as stated, the same was known to the late Dr Elliotson, to the late Dr Engledue, and to Messrs Atkinson and Syme of London, including others who may be nameless. It is not *now*, as it was *then*, so really dangerous to announce the discovery of things new and strange. The present age *is*, we hope, less illiberal than I knew and even felt it to be at the time referred to. Doctors Hitzig and Ferrier would not be reaping the happy harvest of their very commendable labours if things were not now altered for the better."

It is clear, then, that the correspondence of the motor areas of Ferrier with the phrenological organs, of which the particular motions are the natural expression, was discovered by Gall and was well known to all the early phrenologists; but the modern writers, owing to their ignorance of phrenology, have denied this correspondence. It has, however, been clearly pointed out by Dr Bernard Hollander, M.D., at the British Association in 1890, and before the Anthropological Institute in 1889 and 1891; and also by Mr James Webb, late President of the British Phrenological Association, in his "Phrenological Aspect of Modern Physiological Research" (1890).* A few of the examples, beginning with those adduced by Dr Hollander, will be here summarised, but the original papers must be consulted for the full evidence.

Professor Ferrier excited a definite portion of the ascending frontal convolution in monkeys and several other animals, which had the effect of elevating the cheeks and angles of the mouth with closure of the eyes. On no other region could the same effect be produced. Now the expression of joy or amusement is the drawing back the corners of the mouth, forming an incipient smile. All the authorities agree in this. General paralysis of the insane is almost always accompanied by optimism and constant joyousness, accompanied by delusions as to wealth and grandeur; and the earliest physical symptom of the disease is a trembling at the corners of the mouth and the outer corners of the eyes. Now the brain-centre producing these effects corresponds in position to the phrenological organ of hope, the manifestation of which is cheerfulness and especially cheerful anticipations.

Professor Ferrier also discovered a centre for facial

* See *Journal of the Anthropological Institute*, vol. xix. p. 12, and vol. xx. p. 227.

movements, and this exactly corresponds with the phrenological organ of imitation, which gives the power of mimicry, of which facial expression is the most important part.

Another centre was found which produced motions of the tongue, cheek pouches, and jaws in monkeys, exactly as in tasting; and this spot corresponds with the organ of gustativeness, which gives appreciations of flavours, and in its excess makes a man a gourmand.

A most remarkable correspondence is that of the organ of concentrativeness, which gives the power of continued attention to any subject, and is the centre of visual ideation. It is not the centre of *vision*—that is situated in another part of the brain—but of the faculty of giving special attention to definite visual objects. Its outward manifestation is a fixed gaze; and as sight is by far the most important of the senses as regards giving us knowledge of the outer world, concentration of attention would be first developed through vision, and a fixity of gaze has become an outward indication of continuous thought on any subject, even non-visual. The person is said to exhibit "rapt attention."

One more correspondence noted by Dr Hollander may be given—that of the centre for motions indicating anger with the phrenological organ of destructiveness. The excitation of this centre caused jackals to retract the ears and spring forward; in cats opening the mouth, with spitting and lashing the tail—all indications of anger. Now destructiveness—perhaps badly named—is simply the organ of anger or passion; and unrestrained passion, whether in children or adults, is usually manifested by injury or destruction of the offending object; the child beats or breaks what has hurt it, while the despot tortures or kills the person who seriously angers him.

Mr Webb gives illustrations from several other organs which are equally interesting. When Dr Ferrier's centre (1) was excited in monkeys, the animal "extended its legs." This centre is in the position of the phrenological organs of firmness and self-esteem, one outward expression of which is the stretching the legs or putting down the feet with determination, whence has arisen a proverbial expression for obstinacy. Excitation of centre (12) caused the "eyes to open widely, the pupils to dilate, and head and eyes to turn to the other side." Now this centre corresponds to the phrenological organ of wonder, and nothing could better express wonder than the motions described. Even more curious was the result of exciting the lower part of the inferior occipital convolution of cows and sheep, which "caused uneasy movements of the hind legs and tail, while the animals looked to the opposite hind leg and occasionally uttered a plaintive cry, as if of pain or annoyance." The part excited is the phrenological organ of philoprogenitiveness or love of offspring, and anyone who has watched a cow whose calf has been taken away must recognise the accurate description of the motions by which she expresses her feelings.

Now, surely, this close correspondence of "motor centres" with the phrenological organs of which the actions or motions under excitation are the natural expression is very remarkable, and affords a new and striking test of the accuracy with which the phrenologists have localised the brain centres for the various mental faculties. With such confirmation as regards many of the motor centres yet discovered, the presumption is in favour of the accurate determination of other phrenological organs, more especially as their development also accords with, and explains, national and race character, which neither physiologists nor anthropologists have even attempted to do; while as re-

gards individual character, the skilled phrenologist has shown that he is able to read it like an open book, and to lay bare the hidden springs of conduct with an accuracy that the most intimate friends of the individual cannot approach. Yet, even now, the advocates of this new and very crude method of brain study repeat the old vague objections to phrenology as if they were true and unanswerable. After the reading of Dr Hollander's first paper at the Anthropological Institute, Professor Ferrier, while complimenting the author, and making no objections to his facts, went on to say: "What we wanted was evidence founded on careful investigation according to strictly scientific methods, serving to indicate a relation between the development of particular centres and special mental faculties, aptitudes, or peculiarities. At present he did not think there was any such worthy of consideration." But were not Gall's and Spurzheim's and Combe's life-long investigations "careful" and their methods "scientific"? And were not their final conclusions justified by that best test of all true theory, the power of prediction of character in its most minute details? Life-long and class prejudices always die hard, but it is surely now time that this wholly unjustifiable accusation of phrenology being "unscientific" should be abandoned, since it is really founded on a far more scientific basis than that of the modern school, who, by an utterly unnatural and, therefore, "unscientific" mode of exciting the brains of living animals, hope to arrive at a correct knowledge of its varied functions.

The blinding effects of this prejudice against phrenology has caused these modern investigators to overlook the circumstance that the often complex motions of different parts of the body, resulting from the stimulation of various brain centres, were really the physical expression of mental emotions and of the very same emotions as those long

since assigned to the phrenological organs situated in the same parts of the brain. It is also very suggestive that these experiments lead to nothing of value in the hands of the experimenters. To show that the excitation of one brain centre affects such numerous and varied sets of muscles as are required to cause movements of the hind legs, the tail, the head, and the vocal organs of a cow; while excitation of another centre produces movements of the ear and of all four limbs in a jackal, but of the tail, mouth, and tongue in a not very remote species—the cat—are facts which, standing alone, are unmeaning and worthless. But all these movements and many others become quite intelligible when looked upon as not the immediate but the secondary effects of the stimulation, being the various modes of expression of the mental emotions which constitute the actual functions of the parts excited, and the expression of which varies according to the organisation and habits of the several animals. Instead of being, as so often alleged, a disproof of phrenology, or in any way antagonistic to it, these modern investigations are only intelligible when explained by means of its long-established facts, and thus really furnish a most striking and most convincing, because wholly unintended, confirmation of its substantial truth.

Since this chapter was written, Dr Hollander has published his large and important volume, "The Mental Functions of the Brain," in which he not only shows and illustrates the great work done by Gall, but by a research through medical literature, and an extensive record of cases observed by himself and others in asylums and hospitals, demonstrates the localisation of functions, and proves that such localisation very closely accords with the determinations of Gall and of the best modern phrenologists. The book is well and copiously illustrated, and is

indispensable to every student of the brain as the organ of the mind. A more recently published work by the same author, "Scientific Phrenology," deals more directly with the subjects discussed in the present chapter, and demonstrates the vital importance of this hitherto neglected science.

Let us now briefly state the main principles of phrenology, all at first denied, but all now forming part of recognised science.

(1) The brain is the organ of the mind.

This was denied in the *Edinburgh Review*, and even J. S. Mill wrote that "mental phenomena do not admit of being deduced from the physiological laws of our nervous organisation."

(2) Size is, other things being equal, a measure of power. This was at first denied, but is now generally admitted by physiologists.

(3) The brain is a congeries of organs, each having its appropriate faculty.

Till a comparatively recent period this was denied, and the brain was said to act as a single organ. Now it is admitted that there are such separate organs, but it is alleged that they have not yet been discovered.

(4) The front of the brain is the seat of our preceptive and reflective faculties; the top, of our higher sentiments; the back and sides, of our animal instincts.

This was long denied; even the late Dr W. B. Carpenter maintained that the back of the brain was probably the seat of the intellect! Now almost all physiologists admit that this *general* division of brain organs is correct.

(5) The form of the skull during life corresponds so closely to that of the brain that it is possible to determine the proportionate development of various parts of the latter by an examination of the former.

The denial of this was, we have seen, the stock objection

to the very possibility of a science of phrenology. Now it is admitted by all anatomists. The late Professor George M. Humphry of Cambridge University, in his "Treatise on the Human Skeleton" (p. 207), expressly admits the correspondence, adding: "The argument against phrenology must be of a deeper kind than this to convince anyone who has carefully considered the subject."

It thus appears that the five main contentions of the phrenologists, each of them at first strenuously denied, have now received the assent of the most advanced modern physiologists. But admitting these fundamental data, it evidently becomes a question solely of a sufficiently extended series of comparisons of *form* with *faculty* to determine what faculties are constantly associated with a superior development of any portion of the cranium and of the brain within it. To assert that such comparisons are unscientific, without giving solid reasons for the assertion, is absurd. The whole question is, are they adequate? And the one test of adequacy is, do they enable the well-instructed student to determine the character of individuals from the form of their skulls whenever any organ or group of organs is much above or below the average? This test was applied by the early phrenologists, in scores, in hundreds, even in thousands of cases, with a marvellous proportion of successful results. The men who first determined the position of each organ only did so after years of observation and hundreds of comparisons of development of organs with manifestation of function. These determinations were *never* blindly accepted, but were tested by their followers in every possible way, and were only generally admitted when every ordeal had been passed successfully. To reject such determinations without full examination of the evidence in support of them, without applying any of the careful tests which the early phren-

ologists applied, and on the mere vague allegations of insufficient observation or unscientific method, is itself utterly unscientific.

In the present century phrenology will assuredly attain general acceptance. It will prove itself to be the true science of mind. Its practical uses in education, in self-discipline, in the reformatory treatment of criminals, and in the remedial treatment of the insane, will give it one of the highest places in the hierarchy of the sciences; and its persistent neglect and obloquy during the last sixty years of the nineteenth century will be referred to as an example of the almost incredible narrowness and prejudice which prevailed among men of science at the very time they were making such splendid advances in other fields of thought and discovery.

CHAPTER XXI

THE OPPOSITION TO HYPNOTISM AND PSYCHICAL RESEARCH

"Speak gently of the new-born gift, restrain the scoff and sneer,
And think how much we may not learn is yet around us here;
What paths there are where faith must lead, and knowledge cannot share,
Though still we tread the devious way, and feel that truth is there."

ANON. (1844).

"Sleep, sleep on! forget thy pain;
My hand is on thy brow,
My spirit on thy brain;
My pity on thy heart, poor friend;
And from my fingers flow
The powers of life, and like a sign,
Seal thee from thine hour of woe."

SHELLEY.

ALTHOUGH the subjects to be now discussed have made some progress during the last quarter of the century, this was preceded by a long period of ignorance, accompanied by the most violent opposition, extremely discreditable to an age of such general research and freedom of inquiry in all other branches of human knowledge. A brief outline of the nature of this opposition will be interesting, and may serve as a warning to those who still put faith in the denunciations of the public press, or of those writers who pose as authorities without having devoted any serious study to the subject.

The phenomena of animal magnetism, often termed mesmerism, and now hypnotism, were discovered by a physician of Vienna named Mesmer about the year 1770. He applied it to the treatment of disease, and obtained

great popularity in Paris, where he came to practise. His knowledge of the subject was, however, necessarily limited, and his interpretation of the facts often erroneous. A Government Commission was appointed in 1785, consisting of physicians and scientists (including Lavoisier, Franklin, and other eminent men) who, finding that many of the phenomena, alleged by Mesmer to be due to a special form of magnetism, could be produced in the patients by suggestion, reported against his alleged powers, and the subject soon fell into disrepute.

Early in the nineteenth century, however, the phenomena again occurred in the practice of some physicians in Paris and elsewhere, a few of whom devoted much time to the study, and obtained evidence of the most perfect thought-reading, true clairvoyance, and many other apparently superhuman powers. Many medical men became satisfied of the genuineness of these strange occurrences, and the amount of interest they excited in the scientific and medical worlds is shown by the fact that the article "Magnetisme" in the "Dictionnaire de Médecine," published in 1825, treated the subject in a serious spirit, and recognised the whole of its phenomena as being undoubtedly genuine. The writer, Dr Rostan, declares that he had himself examined a clairvoyante who, when he placed his watch at the back of her head, told the time indicated by it, and even when he turned the hands round without looking at them, was equally successful.

Of course, those who had no opportunity of investigating the subject under favourable conditions could not accept such marvels, and imputed them to clever trickery; and in order to determine authoritatively how much truth there was in the statements of the animal magnetisers, the Académie Royale de Médecine, in 1826, appointed a committee of eleven members, all, of course, medical men,

and presumably capable and impartial, to inquire into the whole subject experimentally. Nine of the members attended the meetings and experiments during five years; and in 1831 they delivered a full and elaborate report, which was signed by the whole nine, and was therefore unanimous. This report (published in the "Archives Generale de Médecine," vol. xx.) gives the details of a large number of experiments, and concludes with the summary of what was considered to be proved, together with some weighty observations. As this report is very little known, and has been completely ignored by almost all writers adverse to the claims of the magnetisers, I will give some of the more important portions of it, as translated by Dr Lee in his work on animal magnetism.

Report of the Commission of the Académie Royale de Médecine on Animal Magnetism

"Conclusions and General Remarks"

"The commission has reported with impartiality that which it had seen with distrust; it has exposed methodically that which it has observed under different circumstances, and which it has followed up with an attention as close as it is continued. It has the consciousness that the statements which it presents to you are the faithful expression of that which it has observed. The obstacles which it has met with are known to you; they are partly the cause of the delay which has occurred in presenting the report, although we have long been in possession of the materials. We are, however, far from excusing ourselves, or from complaining of this delay, since it gives to our observations a character of maturity and reserve which should lead you to confide in the facts which we have related, without the charge of prepossession and enthusiasm with which you might have reproached us if we had only recently collected them. We add that we are far from thinking that we have seen all that is to be seen, and we do not pretend to lead you to admit as an axiom that there is nothing positive in magnetism beyond what we mention in our report. Far from placing limits to this part of physiological science, we entertain, on the contrary,

the hope that *a new field* is opened to it; and guaranteeing our own observations, presenting them with confidence to those who, after us, will occupy themselves with magnetism, we restrict ourselves to drawing the following conclusions, which are the necessary consequence of the facts the totality of which constitutes our report."

A considerable proportion of these "conclusions" relate to points which are either unimportant or now undisputed, such as the mode of magnetising, the proportion of persons who can be magnetised, the influence of expectation, the variety of phenomena produced, the possibility of simulation, the nature of the magnetic sleep, the therapeutic effects produced, and their importance, and other similar points. The following paragraphs give the more important of the "conclusions," referring to those points which are still doubted or denied by a considerable number of men of science:—

"It has been demonstrated to us that the magnetic sleep may be produced under circumstances in which the magnetised have not been able to perceive, and have been ignorant of, the means employed to occasion it.

"When a person has been already magnetised, it is not always necessary to have recourse to contact or to the 'passes' in order to magnetise afresh. The look of the magnetiser, his will alone, has often the same influence. In this case one can not only act upon the magnetised, but throw him completely into the sleep, and awaken him from this state without his being aware of it, out of his sight, at a certain distance, and through closed doors."

. . . .

"We have seen two somnambulists distinguish *with closed eyes* the objects placed before them; they have designated, *without touching them*, the colour and name of cards; they have read words written, or lines from a book. This phenomenon has occurred even when the eyelids *were kept closed by the fingers*.

"We have met with two somnambulists who possessed the faculty of foreseeing acts of the organism, more or less distinct, more or less complicated.

"We have only met with one somnambulist who could indicate the symptoms of the diseases of three persons with whom she was

placed in relation. We had, however, made researches on a considerable number."

. . . .

"The commission could not verify, because it had no opportunity, the other faculties which magnetisers had stated to exist in somnambulists. But it has collected, and it communicates to the Academy, facts sufficiently important to induce it to think that the Academy ought to encourage researches on magnetism as a very curious branch of psychology and natural history.

"Certainly we dare not flatter ourselves that we shall make you share entirely our conviction of the reality of the phenomena which we have observed, and which you have neither seen, nor followed, nor studied with or in opposition to us. We do not, therefore, exact from you a blind belief in all that we have reported. We conceive that a great part of the facts are so extraordinary that you cannot grant it to us: perhaps we ourselves should have refused you our belief if, changing places, you had come to announce them before this tribunal to us, who, like you at present, had seen nothing, observed nothing, studied nothing, followed nothing of them.

"We only require you to judge us as we should have judged you—that is to say, that you remain perfectly convinced that neither the love of the wonderful, nor the desire of celebrity, nor any interest whatever, has influenced our labours. We were animated by motives more elevated, more worthy of you, by the love of science, and by the wish to justify the hopes which the Academy had conceived of our zeal and devotedness.

"(Signed) BOURDOIS DE LA MOTTE (*President*),
FOUQUIER,
GUENEAU DE MUSSY,
GUERSENT,
ITARD,
LEROUX,
MARC,
THILLAGE,
HUSSON (*Reporter*)."

It is hardly possible to have a weightier or more trustworthy report than this one, showing in every line the care and deliberation of the members of the commission, while

their competence and honesty are above suspicion. The same general conclusions as to the reality and importance of animal magnetism were arrived at by some of the most eminent physicians in Russia, Denmark, Saxony, and other countries; while the entire report of the French Commission was transmitted into English in 1836 and published in Mr Colquhoun's "Isis Revelata."

In 1837, however, in consequence of many accounts of clairvoyance then occurring in various parts of France, the Académie de Médecine offered a prize of three thousand francs to anyone who should prove his ability to read without use of the eyes. The daughter of a physician at Montpelier—Dr Pigeaire—possessed this power, as testified by many persons of repute; and, in consequence of this offer, he brought her to Paris. Many persons saw her in private, and several physicians—MM. Orfila, Ribes, Reveillè-Parise and others—certified the fact of her clairvoyant powers. But the members appointed by the Academy—less experienced than those of the Commission of 1831—began by making stipulations as to the complete enclosure of the clairvoyant's head, to which her father would not consent, and thus the opportunity of officially testing this lady was lost.* Others presented themselves, but none succeeded. The result was, therefore, purely negative; but as there were in some cases suspicions of imposture or attempts at imposture, the report was, of course, against the existence of clairvoyance. This was only what might have been anticipated by all who had really investigated the subject. Professor William Gregory of the University of Edinburgh, after twenty years' study

* The method usually adopted was to bind a linen cloth over the eyes, to cover this with cotton-wool, and over all a black velvet mask, which was held to be a complete test by Arago and other observers. This, however, the commissioners would not even try.

of animal magnetism and an extensive personal experience, wrote as follows :—

> "In regard to clairvoyance, I have never seen it satisfactorily exhibited except quite in private; and in this point my experience has simply confirmed the statements made by the best observers. I feel confident that every one who chooses to devote some time and labour to the investigation may meet with it either in his own case or those of his friends."

In his "Letters on Animal Magnetism" Professor Gregory gives several indisputable cases tested by himself. Dr Haddock, Major Buckley, Sir Walter Trevelyan, Miss Martineau, Dr Esdaile, Dr Lee, and Dr Elliotson, have all obtained evidence of the most convincing kind, much of which has been published; while many eminent physicians and men of science on the Continent obtained equally convincing results, all confirming the positive evidence of the French Commission of 1831, and proving that the negative results of the Commission of 1837 were due to the inexperience and prejudices of the members. Yet, notwithstanding this cumulative proof, modern writers against the higher phenomena produced by hypnotism appear to be either totally ignorant of the existence of the five years' inquiry and elaborate report of the first Commission of the Académie de Médecine, or confound it with the second commission, which gave a purely negative report on one limited phase of the phenomena!

Thus the late Dr W. B. Carpenter, in his volume on "Mesmerism, Spiritualism, etc., Historically and Scientifically Considered" (Longmans, 1877), writes as follows :—

> "It was in France that the pretentions of mesmeric *clairvoyance* were first advanced; and it was by the French Academy of Medicine, in which the mesmeric state had been previously discussed with reference to the performance of surgical operations,

that this new and more extraordinary claim was first carefully sifted, in consequence of the offer made in 1837 by M. Burdin (himself a member of that Academy) of a prize of 3000 francs to anyone who should be found capable of reading through opaque substances."

Neither here, nor in any part of his volume, does Dr Carpenter show any knowledge of the existence of the Commission of 1825-31, which really "first carefully sifted" the varied phenomena of animal magnetism, including numerous cases of clairvoyance, and decided that they were genuine.

In the last edition of Chambers' "Encyclopedia" (1890), a publication remarkable for the great ability of its contributors and the impartial treatment of disputed questions, we find in the article "Animal Magnetism" the following passage:—"Despite the unfavourable report of the French Commission of 1785, as well as of a later one in 1831, and other subsequent exposures," . . . indicating that the writer was unacquainted with the highly favourable report of 1831 and confused it with the negative report of 1837-40. And this ignorance is confirmed by the statement, a little further on, that "no scientific observer has yet confirmed the statements of mesmerists as to clairvoyance, reading of sealed letters, influence on unconscious persons at a distance, or the like,"—a statement the exact opposite of the fact, since the nine members of the Commission of the Academy of Medicine, Professor Gregory and the other gentlemen mentioned above, as well as a large number of physicians and others on the Continent, must surely be held to be, individually and as a whole, "scientific observers," or the term can have no meaning. Büchner, Spitta, and other antagonistic Continental writers, also appealed to the Commission of 1784 as having exposed "the swindle of magnetic cures," apparently in complete

ignorance of the report of 1831; and Büchner also refers to the Commission of 1837 as reporting against clairvoyance without any reference to the more weighty report of 1831 in its favour.

One more example as to the mode of treatment of evidence for the reality of clairvoyance. Dr Carpenter describes some of his own visits to Alexis and Adolphe Didier, accompanied by Dr Forbes; and because they saw nothing which was to them absolutely conclusive, he leads the reader to think that nothing really conclusive had ever been obtained. But Dr Lee, a physician of repute, and therefore presumably as good a witness as Dr Carpenter or Dr Forbes, in his well-known work on animal magnetism, devotes twenty-two pages to an account of his own personal experiments with Alexis at Brighton in 1849, including such a number and variety of striking tests as to entirely outweigh any number of *negative* results like those of Dr Carpenter. And in addition to these, other special tests of the most stringent character have been published, two of which may be here given. Sergeant Cox, in his "What Am I?" (vol. ii. p. 167) describes a test by a party of experts of whom he was one. A word was written by a friend in a distant town, and enclosed in an envelope, *without any one of the party knowing what the word was.* This envelope was enclosed successively in six others of thick brown paper, each sealed. This packet was handed to Alexis, who placed it on his forehead, and in three minutes and a half wrote the contents correctly, imitating the very handwriting. Let anyone compare Dr Carpenter's explanation of how he supposed such readings were done, and he will see how completely inadequate it is as applying to tests such as that of Sergeant Cox and scores of other inquirers.

The next test is furnished by the experience of the

greatest of modern professional conjurers, Houdin, who, at the request of the Marquis de Mirville, had two sittings with Alexis. His account, as quoted by Dr Lee, is as follows. After describing what took place at the first sitting, he says:

"I cannot help declaring that the facts here reported are perfectly exact, and that the more I reflect upon them the more impossible do I find it to class them with those which constitute the object of my art." (10th May 1849.)

"At the second *séance* I witnessed still more surprising events than at the first, and they no longer leave any doubt in my mind respecting the clairvoyance of Alexis. I tear off the envelope of a pack of cards I brought with me. I shuffle and deal with every precaution, which, however, is useless, for Alexis stopped me by naming a card which I had just placed before him on the table. 'I have the king,' said he. 'But you know nothing about it, as the trump card is not turned up.' 'You will see,' he replied; 'go on.' In fact, I turned up the ace of spades, and his card was the king of spades. The game was continued; he told me the cards which I should play, though my cards *were held closely in my hands beneath the table*. To each of the cards I played he followed suit, *without turning up his cards*, which were always perfectly in accordance with those I led. I therefore returned from this *séance* as astonished as one can be, and I am convinced that it is quite impossible that chance, or any superior skill, could produce such wonderful results." (16th May 1849.)

Now the point which I wish to submit to my readers is whether the method of argument and discussion adopted by the most eminent opponents of animal magnetism is either honest, or scientific, or even rational. We do not ask them to accept blindly any of the facts reported, or to refrain from any criticism, however severe, which is founded upon a fair consideration of all the available evidence. But in this matter, as I have here shown by a few striking examples, the public mind is influenced by the omission to state the case fairly; by putting forth the weakest instead of the strongest facts and arguments; and

by the denial that any good and trustworthy evidence exists. What should we think of the man who discussed any of the disputed questions of recognised science in this way? who either ignorantly or wilfully omitted all reference to the most careful researches of the most eminent writers on the subject; and, while professing to instruct and enlighten the public, led them to believe that such researches did not exist? Such a man would at once lose all claim to be considered an authority on any subject, and his future writings would be treated with deserved neglect. It is because, during the greater part of the century, this most important and most interesting inquiry has been treated in so unworthy a manner by men of reputation in other departments of research that we are compelled to class the opposition to the phenomena of mesmerism, and especially to the reality of clairvoyance, as constituting one of the exceptions to the steady march of most branches of science throughout the century.

We now come to the consideration of a practical application of animal magnetism, the opposition to which was even more virulent and more unjustifiable than that just described. The subject of mesmerism, as it began to be termed, was first introduced into this country by Mr Richard Chenevix, a Fellow of the Royal Society, who published a series of papers in the *London Medical and Physical Journal* in 1829. He also exhibited the phenomena to numerous medical men, among others to Dr Elliotson, who afterwards became one of the chief teachers of the science. The Professor of Physiology at King's College, Dr Herbert Mayo, also upheld and wrote upon it in the medical journals. Baron Dupotet came to London, and again demonstrated the main facts, as did numbers of public lecturers, affording ample opportunities for experiment and observation.

In 1829 M. Cloquet, one of the most eminent surgeons of Paris, amputated a cancerous breast during the mesmeric sleep, the patient being entirely insensible to pain, although able to converse. Teeth were extracted, and many other operations, some very serious, such as the extirpation of a portion of the lower jaw, in the hospital of Cherbourg, were performed in France. About twelve years later operations in the mesmeric trance began to be performed in England; but, notwithstanding the numerous cases already reported from France, supporting the fact of insensibility to pain, as fully described by the Academy of Medicine, they were received with general incredulity by the medical profession, while the most outrageous accusations were made against all who took part in them.

On the 22nd of November 1842 at the Royal Medical and Chirurgical Society of London, an account was read of the amputation of the thigh during the mesmeric trance. The patient was a labourer who had suffered for five years with neglected disease of the left knee, the slightest motion of the joint being attended with extreme pain. Before the operation he had had no sleep for three nights. He was mesmerised by Mr W. Topham, a barrister, and operated upon by Mr W. Squire Ward, surgeon in the District Hospital of Wellow, Nottinghamshire. During the whole operation, lasting twenty minutes, the patient remained in perfect repose, the placid countenance never changing, while no muscle of the body or limbs was seen to twitch. He awoke gradually and calmly, and on being questioned, declared that he knew nothing that was being done, and had felt no pain at all. He recovered perfectly, and had not a single bad symptom.

Then followed a violent discussion. Mr Coulson said the non-expression of pain was a common thing, and he had no doubt the man had been trained to it. Several

declared that the man shammed. One declared he would not have believed the facts had he witnessed them! Then the great men of the profession spoke. Dr Marshall Hall, the investigator of reflex action, declared that it was a case of imposition, because the sound leg should have contracted when the diseased leg was cut. The case, therefore, contradicted itself. Sir Benjamin Brodie believed that the man must have been naturally insusceptible to pain. He also agreed with Dr Marshall Hall that the other leg ought to have moved, and he was quite satisfied with the two French reports against mesmerism. Mr Liston and Mr Bransby Cooper made fun of the subject; but Dr Mayo declared it was a paper of great importance, and should not be ridiculed. Mr Wood, who had assisted at the amputation, vouched for the complete accuracy of the whole account, and pointed out that before the operation the patient *had* suffered intense pain, and that during the operation he not only showed no sign of pain but no sign of resistance to the expression of pain. Dr Elliotson also pointed out the illogical nature of the objections; but the opponents, who were all completely ignorant of the subject, at the next meeting refused confirmation of the minutes, which were therefore expunged!

Here we have extreme ignorance in high places, denying facts which had been observed again and again by men as honest and trustworthy as themselves. It was these men, and others equally ignorant, who accused the operators of bribing their patients not to exhibit pain; who accused Dr Elliotson of "polluting the temple of science"; and who ejected this eminent physician from his professorship in the University of London because he persisted in studying the phenomena of mesmerism and in publishing the results of his experiments. He was, however, soon justified in the eyes of all the more honest members of the

profession by the publication of so many cases of painless operations as to compel their acceptance as facts; * while he was supported by Dr Esdaile, who gave an account of more than 300 operations performed by himself and other surgeons in the hospitals of Calcutta, which were confirmed by a commission appointed to inquire into them by the Bengal Government and by the Governor-General himself. The reports of these cases showed that the patients were equally subject to the charge of imposition because they did not exhibit reflex action in the opposite limb; and Dr Elliotson made this point the subject of some justifiable ridicule. He says: "It is really lamentable to know that this Asiatic practised imposition as boldly as the female in Europe. The Indian was convicted through the self-same piece of ignorance. He, too, was unaware that he ought to have moved his right elbow-joint if he felt nothing while his left was being cut off; and so he did not stir it. The dark races are just as wicked and just as ignorant of physiology as the white."

The facts, however, accumulated so rapidly and were so well attested that a few years later Dr Noble, Sir John Forbes, and Dr W. B. Carpenter accepted them; thus admitting that the great men who denied them were wholly in the wrong, and that they had displayed ignorance and prejudice in their accusations of imposture and bad faith. But just when the great importance of mesmerism in rendering the most serious operations painless, and at the same time greatly assisting the patient's recovery, was fully acknowledged, the discovery of anæsthetics occurred; and this physiological agent, being more easy to apply and more certain to act upon all patients, soon led to the neglect of mesmerism. With this neglect the old

* "Numerous Cases for Surgical Operations without Pain in the Mesmeric State," by John Elliotson, M.D., F.R.S. London, 1843.

prejudices and incredulity revived; and, although its soothing and remedial influence in disease was quite as well established as its use in surgery, it soon fell into disuse, and the great majority of medical men came to look upon it as either disreputable or altogether a delusion.

For nearly half-a-century it remained in abeyance, till its study was revived in the French hospitals, where all the phenomena described by the early mesmerisers have been reobserved, together with some others even more extraordinary.

During the latter portion of the century the study of these and other obscure psychical phenomena has become more extended, and in every civilised country societies have been formed for investigation, and many remarkable works have been published. One after another, facts, long denied as delusions or exaggerations, have been admitted to be realities. The stigmata, which at different times have occurred in Catholic countries, are no longer sneered at as priestly impostures. Thought-transference, automatic-writing, trance-speaking, and clairvoyance, have been all demonstrated in the presence of living observers of undoubted ability and knowledge, as they were demonstrated to the observers of the early part of the century and carefully recorded by them. The still more extraordinary phenomena — veridical hallucinations, warnings, detailed predictions of future events, phantoms, voices or knockings audible to numerous individuals at once, bell-ringing, the playing on musical instruments, stone-throwing, and various movements of solid bodies, all without human contact or any discoverable physical cause—still occur among us as they have occurred in all ages. These are now being investigated, and slowly but surely are proved to be realities, although the majority of scientific men and of writers for the press still ignore the cumulative

evidence and ridicule the inquirers. These phenomena, being comparatively rare, are as yet known to but a limited number of persons; but the evidence for their reality is already very extensive, and it is absolutely certain that, during the present century, they too will be accepted as realities by all impartial students and by the majority of educated men and women.

The great lesson to be learnt from our review of this subject is distrust of all *à priori* judgments as to *facts*; for the whole history of the progress of human knowledge, and especially of that department of knowledge now known as psychical research, renders it certain that, whenever the scientific men or popular teachers of any age have denied, on *à priori* grounds of impossibility or opposition to the "laws of nature," the facts observed and recorded by numerous investigators of average honesty and intelligence, these deniers *have always been wrong*.*

Future ages will, I believe, be astonished at the vast amount of energy and ignorance displayed by so many of the great men of the nineteenth century in opposing unpalatable truths and in supposing that *à priori* arguments, accusations of imposture or insanity, or personal abuse, were the proper means of determining matters of fact and of observation in any department of human knowledge.

* For a discussion of this point, with illustrative cases, see my "Miracles and Modern Spiritualism," pp. 17-29.

CHAPTER XXII

MILITARISM—THE CURSE OF CIVILISATION

1. Crime and Punishment

"They love the most who are forgiven most,
And when right reason slowly dawns once more
On the wild madness of a moral fiend—
Our brother still and God's beloved child—
There comes a mighty gush of gratitude,
Thawing the hoar frost of a life of crime,
Breaking the icy barriers of self-love,
While all the loosened rivers of the soul
Spring from their fountains radiant in the light."
T. L. Harris.

"The vilest deeds, like poison weeds,
Bloom well in prison air;
It is only what is good in Man
That wastes and withers there;
Pale Anguish keeps the heavy gate,
And the Warder is Despair."
The Ballad of Reading Gaol.

The first half of the nineteenth century produced much good work that has not been further developed, many bright promises that have not been fulfilled. The great amelioration of the criminal law by the exertions of Sir Samuel Romilly, Sir James Mackintosh, and other reformers have not been succeeded by any corresponding reform of our system of punishment as a whole, which still remains thoroughly inhuman and unjust, and opposed to all the admitted principles by which punishment among a civilised people should be regulated. At the beginning of the century about twenty-five offences were punishable

with death, including burglary, stealing from a house or shop to the value of 40s., forgery, coining, using old stamps on perfumery and hair powder, sheep and horse stealing, and many others. Capital punishment for all these minor offences was abolished before the middle of the century; our prisons were greatly improved as regards cleanliness and order; and transportation to Tasmania and the other Australian colonies, with all its cruelties and abuses, had been got rid of. But there we have stopped; and our treatment of criminals, though not outwardly so harsh, is quite as much opposed to the admitted principles which should regulate all punishment as it was before; while its effects are hardly, if at all, less injurious to the criminals, both as regards bodily and mental health, than the old bad system of the eighteenth century.

Even Plato and other classical writers laid down the principle that one of the great objects of all punishment is the improvement of the criminal. Beccaria in the eighteenth century developed this view of the true rationale of punishment, and all modern students and philanthropists admit it; yet during the century which has just expired we have not made a single step in this direction as regards the treatment of adult prisoners. A cast-iron routine, solitude, and a grinding military despotism under which the best men often suffer most, now characterises our penal system, which is admitted to have the effect of making the good bad and the bad worse; and further, of rendering it almost impossible for a first offender to escape from a life of crime. There is no classification of offenders; no sympathetic instruction; no attempt to improve the character; no preparation for an honest life; no means afforded the discharged prisoner of entering upon an honest life. We have, again and again, been shown what modern penal servitude is like by educated men who have endured

it. They all tell us that it is a hell upon earth; that its tendency is to crush out every human feeling or higher aspiration; and that it sends the majority of those who endure it back to the outside world worse in character and less capable of living honestly than they were before they entered the prison walls. The system is utterly unchristian, utterly opposed to civilisation or philosophy or common sense; yet it remains in full force to-day, and neither governments nor legislators seem to think it a matter of sufficient importance to devote the necessary time and study to its radical reform.

It must be admitted that in our prison system we see one of the most terrible failures of the boasted civilisation of the nineteenth century.

The Lunacy Laws

In an allied department, the confinement of the insane, there is also much room for reform. Their actual treatment, both in public and private asylums, has of late years undergone enormous improvement, and is now almost as good as it can be made in large asylums, where there is no possibility of that proper classification, isolation, and individual treatment which are essential to curative success. But the great evil lies in the existence of private asylums kept for profit by their owners; and in the system by which, on the certificate of two doctors, employed by any relative or friend, persons may be forcibly kidnapped and carried to one of these private asylums, without any public inquiry, and sometimes even without the knowledge or consent of their other nearest relatives or of those friends who know most about them. The well-known cases of Mrs Weldon and Mrs Low prove that perfectly sane

persons may be thus incarcerated, with the possibility of making them insane by association with mad people and all the horrors of a crowded asylum. These two ladies were incarcerated because they were spiritualists—that is, because they held the same beliefs as Sir William Crookes, the Earl of Crawford, Gerald Massey, and myself have held for the last thirty years, and for holding which, to be consistent, we and hundreds of other equally sane persons ought to have been permanently confined as lunatics. The great ability and perfect sanity of those ladies, and their having influential friends, rendered it impossible to keep them permanently confined; but we may be sure that many less able persons have been, and are now, cruelly and unjustly deprived of their liberty, and in some cases are made insane by their terrible surroundings. The great danger of trusting exclusively to professional opinions and statements has been shown in my chapter on hypnotism and my pamphlet on vaccination. It is, therefore, imperative that no person shall be deprived of his liberty on the allegation by any medical authorities of his insanity. The fact of insanity should be decided not by the patient's *opinions* but by his *acts*; and these acts should be proved before a jury, who might also hear medical evidence, before condemnation to an asylum. Asylums for the insane should all belong to public authorities, so that the proprietors and managers should have no pecuniary interest in the continued incarceration of their patients.

So late as 1890 a new and voluminous Lunacy Act was passed, and the public no doubt believe that most of the dangers of the old system are removed. But this is not the case. An examination of this Act shows that private asylums, kept for profit, remain as before. Doctors' opinions are still all powerful. Under an "urgency order," on the certificate of *one doctor*, a person may be

dragged from his or her home to one of these private asylums and kept there for seven days, or till a judicial order is obtained, which may sometimes be delayed for three weeks. This judicial order is given by a duly authorised magistrate, on formal application by some person interested, and the certificates of *two* doctors. The magistrate *may* see the alleged lunatic if he pleases, but he may act on the doctor's and petitioner's statements alone. Whatever inquiry he makes is private; but there is little doubt that in most cases he will act on the medical and other statements before him. Then the alleged lunatic is confined for a year; after that for two years more; then for three years; then for five years, if the medical officer of the asylum reports, before the end of each period, that he is still insane.

And if, either at the first inquiry by the magistrate or afterwards, the patient is declared to be sane, and is discharged, there is no provision for giving the alleged lunatic any information as to the cause of his confinement or the statements of the medical men or the persons' names who caused him to be confined; so that, really, he is still treated as a possible maniac, and is denied redress if his incarcerators have acted illegally. While confined in one of these private asylums the patient's letters to any official *must* be sent, but letters to any other persons, including his nearest relations or friends, are only sent "at the discretion" of the manager. In like manner the visits of relations or friends require an order from a Commissioner in Lunacy or an official visitor of the asylum; but they are not *obliged* to give such an order, so that if the manager of any private asylum states that it is inadvisable, or that it would be injurious to the patient, the order will probably be refused. It thus appears that an alleged lunatic, once in an asylum, is wholly dependent on the doctors for any chance of

getting out again. Everything is in their hands. The patient may be deprived of all communication with friends, either personal or by letter; and though he may see or write to a commissioner, that will avail him nothing if the medical superintendent either mistakenly believes him to be insane or has personal reasons for keeping him in the asylum. From beginning to end there is no publicity, no opportunity of disproving any statements that may be made against him, no means of proving his sanity in open court and subject to the usual safeguards which are accorded to the poorest criminal.

Still more dangerous to liberty is the provision, in sect. 20 of this Act, that any constable, relieving officer, or overseer may remove any alleged lunatic to the workhouse, if *he is satisfied* that this is necessary for the public safety or the welfare of the alleged lunatic. It seems hardly credible, but the judges, in a court of appeal, have decided that any of the above named persons *may act on the private information of one person without seeing the alleged lunatic* or giving him any opportunity to state or prove that he is not a lunatic! Yet they did so decide in March 1898. A Mr Harward quarrelled with his wife, and was rather violent, but did not assault or touch her. Yet she went to the relieving officer and said she was afraid her husband would commit suicide or kill her and the children; and on this statement, without any confirmation and without any personal interview, Mr Harward was taken by force to the workhouse and confined as a lunatic. Being found perfectly sane, he was soon released; and he then brought an action against the Guardians of Hackney Union for false imprisonment. The jury gave him £25 damages on the ground that "the relieving officer had not taken reasonable care to satisfy himself that the plaintiff was a dangerous lunatic." But the judges decided on appeal that there was no evidence to

show that the officer "acted from any other motive than an honest belief," and therefore he was not liable, and the plaintiff had to redress. On such grounds, it is evident that any passionate or violent person may, on a mere statement of a relative professing to fear injury, without any further inquiry, be captured and confined as a lunatic, and have no redress. This is a mere parody of justice. Everyone found to have been confined unjustly, for any cause whatever, should receive a public apology and compensation from the authorities concerned, without being left to appeal to the law, at great expense and trouble, and with the chance of the further injustice of a decision against him.

In view of such cases as this, and of the recent scandalous kidnapping of Miss Lanchester; and of the proved danger of founding legislation on the statements and opinions of doctors and officials in the matter of compulsory vaccination, the actual state of our Lunacy Laws is a permanent danger to liberty and to the free expression of opinion, and is a disgrace to the much-vaunted nineteenth century.

2. The Vampire of War

"Were half the power that fills the world with terror,
Were half the wealth bestowed on Camps and Courts,
Given to redeem the human mind from error,
There were no need for Arsenals and Forts.
The Warrior's name would be a name abhorred!
And every nation that should lift again
Its hand against a brother, on its forehead
Would wear for evermore the curse of Cain!"

LONGFELLOW.

"Since tyrants by the sale of human life
Heap luxuries to their sensualism, and fame
To their wide-wasting and insatiate pride,
Success has sanctioned to a credulous world
The ruin, the disgrace, the woe of War."

SHELLEY.

The first half of the nineteenth century was signalised by the abolition of duelling. It had always been illegal, and had long been considered by every advanced thinker to be both absurd and wicked; but only when forbidden to military men by the War Office did it entirely disappear among civilians. The same public opinion which caused the disappearance of this form of private war equally condemns war between nations as a means of settling disputes, often of the most trivial kind, and rarely of sufficient importance to justify the destruction of life and property, the national hatreds, and the widespread misery caused by it. Yet so far from any progress having been made towards its abolition, the latter half of the century has witnessed a revival of the war spirit throughout Europe; which region has now become a vast camp, occupied by opposing forces greater in numbers than the world has ever seen before. These great armies are continually being equipped with new and more deadly weapons at a cost which strains the resources even of the most wealthy nations, and, by the constant increase of taxation and of debt, impoverishes the mass of the people.

The first International Exhibition, in 1851, fostered the idea that the rulers of Europe would at length recognise the fact that peace and commercial intercourse were essential to national well-being. But, far from any such rational ideas being acted on, there began forthwith a series of the most unjustifiable and useless dynastic wars which the world has ever seen. The Crimean War in 1854-55, forced on by private interests, with no rational object in view, and terrible in its loss of life; the Austro-Prussian War in 1866; the French invasion of Mexico; and the terrible Franco-German War, were all dynastic quarrels, having no sufficient cause and no relation whatever to the well-being of the communities which were engaged in them.

The evils of these wars did not cease with the awful loss of life and destruction of property, which were their immediate results, since they formed the excuse for that inordinate increase of armaments and of the war spirit under which Europe now groans. This increase, and the cost of weapons and equipments, has been intensified by the application to war purposes of those mechanical inventions and scientific discoveries which, properly used, should bring peace and plenty to all, but which, when seized upon by the spirit of militarism, directly tend to enmity among nations and to the misery of the people.

The first steps in this military development were the adoption of a new rifle for the whole Prussian Army in 1846, the application of steam to our ships of war in 1840, and the use of iron armour for the protection of battleships by the French in 1859. The remainder of the century has witnessed a mad race between all the great Powers of Europe to increase the death - dealing power of their weapons and to add to the number and efficiency of their armies; while among the maritime Powers there has been a still wilder struggle, in which all the resources of modern science have been utilised in order to add to the destructive power of cannon and both the defensive and the offensive powers of ships. The various new explosives have been utilised in shells, mines, and torpedoes; rifled cannon of enormous size and power have been manufactured; while battleships of 10,000 to 15,000 tons displacement, protected by steel armour from 10 to 20 inches thick, with enormous engines, often at the rate of one, and recently more than two, horse-power to every ton, driving the ships at a speed of from 12 to 22 knots an hour, have so transformed our fleet that the majority of the ships bear no resemblance whatever to the majestic three-deckers and beautiful frigates with which all our great

naval victories were gained and which formed the bulk of our navy only fifty years ago.

Although the total number of warships and of vessels of all kinds in our fleet are about the same as they were in the middle of the century, their power for offence and defence, and their cost, are immensely greater. Almost all of them are built of iron or steel, and are full of costly machinery; while the torpedo-boats and torpedo-destroyers are adapted for purposes quite different from those of the smaller vessels of our old fleets. Some of our modern first-class armoured turret-ships cost £1,000,000 sterling; and yet, as in the case of the *Vanguard* off Kingstown in 1875, and more recently the *Victoria* in the Mediterranean, they may be sent to the bottom by a chance collision with a companion ship. The huge 110-ton guns cost £20,000 each, and the more common 67-ton gun costs £14,000. All the modern guns, as well as their projectiles, are elaborate pieces of machinery, finished with the greatest perfection and beauty; and it makes any thoughtful person sad to see such skill and labour and so much of the results of modern science devoted to purposes of pure destruction. The six great Powers of Europe now possess about 300 battleships and cruisers, from 2000 up to near 15,000 tons displacement, and nearly 2000 smaller vessels, which are able to destroy life and property to an extent probably fifty-fold greater than the fleets of the first half of the century.

But even this vast cost and loss to modern civilisation is surpassed by that of the armies of Europe. The numbers of men have greatly increased; their weapons and equipments are more costly; and the reserve forces to be drawn upon in time of war include almost the whole male adult populations, for whom reserves of arms, ammunition, and all military supplies must be kept ready. Counting only

the armies of the six great Powers on a peace footing, they amount now to nearly 3,000,000 men; and if we add the men permanently attached to the several fleets, we shall have considerably more than 3,000,000 men in the prime of life withdrawn from productive labour and devoted nominally to defence but really to attack and destruction. This, however, is only a portion of the loss. The expense of keeping these 3,000,000 men in food and clothing, in weapons, ammunition, and all the paraphernalia of war; of keeping in a state of readiness the ships, fortifications, and batteries; of continually renewing the stores of all kinds; of pensions to the retired officers and wounded men, and whatever other expenditure these vast military organisations entail, amounts to an annual sum of more than £180,000,000 sterling.* Now, as the average wages of a working-man (or his annual expenditure), considering the low wages and the mode of living in Russia, Italy, Austria, and the other Continental states, cannot be more than, say, 12s. a week, or £30 a year, an expenditure of £180,000,000 implies the constant labour of at least 6,000,000 men in supporting this monstrous and utterly barbarous system of national armaments. If to this number we add those employed in making good the public or private property destroyed in every war, or in smaller military or naval operations in Europe, we shall have a grand total of about 10,000,000 men withdrawn from all useful or reproductive work, their lives devoted directly or indirectly to the Moloch of war, and who must, therefore, be supported by the remainder of the working community.

And what a horrible mockery is all this when viewed

* This is the amount obtained by adding together the war expenditure of the six great Powers as given in "The Statesman's Year-Book" for 1897.

in the light of either Christianity or advancing civilisation! All these nations, armed to the teeth, and watching stealthily for some occasion to use their vast armaments for their own aggrandisement and for the injury of their neighbours, are Christian nations. Their governments, one and all, loudly proclaim their Christianity by word and deed—but the deeds are usually some form of disability or persecution of those among their subjects who are not orthodox. Of really Christian deeds there are none—no real charity, no forgiveness of injuries, no help to oppressed nationalities, no effort to secure peace or goodwill among men. And all this in spite of the undoubted growth of the true Christian spirit during the last half century. This spirit has even ameliorated the inevitable horrors of war; by some regard for non-combatants, by greatly increased care for the wounded even among enemies, and by a recognition of some few rights, even of savage races.

Never, perhaps, have the degrading influences of the war spirit been more prominent than in the last few years of the century, when all the great Christian Powers stood grimly by while a civilised and Christian people were subjected to the most cruel persecution, rapine, and massacre by the direct orders, or with the consent and approval, of the semi-barbarous Sultan of Turkey. Any two of them had power enough to compel the despot to cease his persecution. Some certainly would have compelled him, but they were afraid of the rest, and so stood still. The excuse was even a worse condemnation than the mere failure to act. Again and again did they cry out: "Isolated action against Turkey would bring on a European war." War between whom? War for what? There is only one answer: "For plunder and conquest." It means that these Christian governments do *not* exist for the good of the governed, still less for the good of humanity

or civilisation, but for the aggrandisement and greed and lust of power of the ruling classes—kings and kaisers, ministers and generals, nobles and millionaires—the true vampires of our civilisation, ever seeking fresh dominions, from whose people they may suck the very life-blood. Witness their recent conduct towards Crete and Greece, upholding the most terrible despotism in the world because each one hoped for a favourable opportunity to obtain some advantage, leading ultimately to the largest share of the spoil. Witness their struggle in Africa and in Asia, where millions of savage or semi-civilised peoples may be enslaved and bled for the benefit of their new rulers. The whole world is now but the gambling table of the six great Powers. Just as gambling deteriorates and demoralises the individual, so the greed for dominion demoralises governments. The welfare of the people is little cared for, except so far as to make them submissive tax-payers, enabling the ruling and moneyed classes to extend their sway over new territories and to create well-paid places and exciting work for their sons and relatives. Hence comes the force that ever urges on the increase of armaments and extension of empire. Great vested interests are at stake; and ever-growing pressure is brought to bear upon the too-willing governments in the name of the greatness or the safety of the empire, the extension of commerce, or the advance of civilisation. Anything to distract attention from the starvation and wretchedness and death-dealing trades at home and the thinly-veiled slavery in many of our tropical or sub-tropical colonies. The condemnation of our system of rule over tributary states is to be plainly seen in plague and famine running riot in India after more than a century of British rule and nearly forty years of the supreme power of the English Government.* Neither plague nor famine

* The Parliamentary Papers recently issued on the Plague in India

occur to-day in well-governed communities. That the latter, at all events, is almost chronic in India, a country with an industrious people and a fertile soil, is the direct result of governing in the interests of the ruling classes instead of making the interests of the governed the first and the only object. But in this respect India is no worse off than our own country. The condition of the bulk of our workers, the shortness of their lives, the mortality among their children, and the awful condition of misery and vice under which millions are forced to live in the slums of all *our* great cities, are, in proportion to *our* wealth and *their* nearness to the centre of government, even more disgraceful than the periodic famines of remote

reveal an insanitary condition of Calcutta and Bombay (and no doubt of most other Indian cities) which is almost incredible; yet we may be sure that it does not err on the side of exaggeration, because it makes known such an utter disregard for the well-being of the Indian peoples, while taxing them to the verge of starvation, as to be nothing less than criminal. These papers, and the discussion on the plague in Bombay at the Society of Arts, also illustrate that unreliability of interested official statements which we have seen to be so prominent a feature of the vaccination question.

In January 1897 the Indian Government sent the Director-General of the Indian Medical Service, Dr Cleghorn, to Bombay to examine personally into the conditions that led to the outbreak, and to recommend the best measures for dealing with it. He made "a thorough investigation of the infected quarters," and this is what he states: About 70 per cent. of the whole native population (about 800,000) live in "chawls" or tenement houses of various sizes, the largest being six or seven storeys high, and holding from 500 to 1000 people each. They consist, on each floor, of a long corridor, with small rooms on each side, about 8 feet by 12 feet, each room inhabited by a family, often of 5 or 6 persons. The sanitary arrangements are utterly inadequate, the consequence being that the corridors, especially at the ends, became receptacles of filth of every kind, and were apparently never thoroughly cleaned. But the greatest evil of all was that these overcrowded tenements were built side by side, often with a space of only three or four feet between them, so that even if the windows were open, in all the lower floors there could be neither adequate light nor ventilation. The privacy of Indian domestic life, however, forbade the opening of these windows, so that practically in half, at least, of the rooms there was neither light nor ventilation. Added to this, the narrow alleys between the chawls, owing to the inadequacy of other accommodation, were used as refuse pits and open sewers, where filth was allowed to accumulate, so that both

India. Both are the results of the same system—the exploitation of the workers for the benefit of the ruling caste—and both alike are among the most terrible failures of the century.

The state of things briefly indicated in this chapter is not progress but retrogression. It will be held by the historian of the future to show that we of the nineteenth century were morally and socially unfit to possess and use the enormous powers for good or evil which the rapid advance of scientific discovery had given us; that our boasted civilisation was in many respects a mere surface veneer; and that our methods of government were not in accordance with either Christianity or civilisation. This

inside and outside there were masses of disease-breeding matter. Even if the rooms and corridors were kept clean, the darkness, the want of ventilation, and the overcrowding would be sources of deadly disease. With the superadded filth inside and out and the tropical climate, the absence, rather than the presence, of plague would seem the more extraordinary phenomenon, since the condition of London in the sixteenth and seventeenth centuries could hardly have been so bad. The same Parliamentary Paper (up to March 1897) contains a Sanitary Inspection Report on Calcutta, which goes much more into detail, and describes a state of things of the most terrible and almost incredible nature. As examples—six men and boys lived and cooked in a room 7 × 7 × 6 feet, which had no window, and with filth and sewage all around. Of another street we read: "The houses are built almost back to back. It would be nearly impossible to squeeze between them; sunlight is so far shut out that, with broad daylight outside the gully, it is absolutely impossible to do more than grope your way within these tenements; rats run about here in the dark as they would at night; a heavy sickening odour pervades the whole place; walls and floors are alike damp with contamination from liquid sewage which lies rotting, and for which there is no escape." There are eight foolscap pages of this report, going into even more horrible details; and there can be no doubt that a large portion of it will apply just as well to Bombay as to Calcutta, and thus enable us to realise more fully the condition of the many hundred thousand dwellers in the worse parts of that plague-stricken city. In the discussion that followed the reading of Mr Birdwood's paper at the Society of Arts, Dr Simpson, late Health Officer in Calcutta—who had been in Bombay assisting the search parties in the plague-stricken districts—stated that, "bad as the houses were in some parts of Calcutta, he found them infinitely worse at Bombay." On the other hand, Mr Acworth, late Municipal Commissioner of Bombay, said that the Bombay "chawls" were not so bad as the Calcutta "bustees," that it was "utterly untrue to say that

view is enforced by the consideration that all the European wars of the century have been due to dynastic squabbles or to obtain national aggrandisement, and were *never* waged in order to free the slave or protect the oppressed without any ulterior selfish ends.

It has been often said that companies have no souls, and the same is still more true of the governments of our day.*

Bombay was a grossly insanitary town," and that it was really the most sanitary large town in India! But the climax of contradiction is reached by the Rev. A. Bowman, late chaplain of Byculla Gaol, Bombay, who stated in a letter to the *Times*, (reprinted in the *Journal of the Society of Arts*, vol. xlvi., p. 333) that he had known the streets and lanes of Bombay intimately for the last five years, and he says, without fear of contradiction, that such places as were described by the Surgeon-General (Dr Cleghorn) do not exist! The reverend gentleman referred especially to "chawls" holding 1000 people, and rooms and corridors which the light of day could not enter; but he apparently did not then know that Dr Cleghorn had made these statements in an official memorandum for the information of the Government of India, or he would hardly have made his contradiction so emphatic.

But what are we to think of a government that has allowed the erection of such tenements in the two chief cities of the empire, and which takes no heed of the most rudimentary principles of sanitation till a visitation of plague compels attention to them?—a government which spends millions on railroads, on gigantic armies, on annexations and frontier wars, on colleges and schools, and on magnificent public buildings, while allowing a considerable proportion of the native population to live in such horribly insanitary conditions as to rival the worst plague-infested cities of Europe in the middle ages. And this is modern civilisation!

* The horrors and barbarities practised by all the troops of the great Powers during their recent invasion of China are a crowning proof of the ever-increasing deterioration of character produced by militarism; while the wars of conquest in South Africa and the Philippines show what a hollow mockery was the great Peace Convention where the representatives of the great Powers, one and all, made the most earnest declarations in favour of Peace and Arbitration!

CHAPTER XXIII

THE DEMON OF GREED

"What of men in bondage, toiling, blunted
In the roaring factory's lurid gloom?
What of cradled infants, starved and stunted?
What of woman's nameless martyrdom?
The all-seeing sun shines on unheeding,
Shines by night the calm, unruffled moon,
Though the human myriads, praying, bleeding,
Put creation harshly out of tune."

MATHILDE BLIND.

"Are these no wrongs of nations to redress;
No misery-frozen sons of wretchedness;
No orphans, homeless, staining with their feet
The very flag-stones of the wintry street;
No broken-hearted daughters of despair,
Forlornly beautiful, to be your care?
Is there no hunger, ignorance or crime?
O that the prophet-bards of old, sublime,
That grand Isaiah and his kindred just,
Might rouse ye from your slavery to the dust."

T. L. HARRIS.

ONE of the most prominent features of the nineteenth century has been the enormous and continuous growth of wealth, without any corresponding increase in the well-being of the *whole* people; while there is ample evidence to show that the number of the very poor—of those existing with a minimum of the bare necessaries of life — has enormously increased, and many indications that they constitute a larger proportion of the whole population than in the first half of the century or in any earlier period of our history.

This increase of individual wealth is most clearly shown

by the rise and continuous increase of millionaires, who, by various modes, have succeeded in possessing themselves of vast amounts of riches created by others, thus necessarily impoverishing those who did create it. Sixty or seventy years ago a millionaire was a rarity. I well remember, in my boyhood, my father reading in the *Times* an account of the death of a man (a merchant, I think) who had left a fortune of a million as something altogether marvellous which he had never heard of before. Now they are to be reckoned by scores, if not by hundreds, in this country, and excite no special remark; while in America, a country having a much larger amount of natural wealth and of human labour to draw upon, they are far more numerous, reaching, it is estimated, about 2000.

In our own country the annual produce of labour from which the expenditure of the whole population necessarily comes, is estimated at £1,350,000,000 sterling; and this amount is so unequally divided that *one* million persons among the wealthy receive more than *twice* as much of this income as the *twenty-six* millions constituting the manual labour class. In America the inequality is still greater, there being 4047 families of the rich who own about five times as much property as 6,599,796 families of the poor.

The causes of this enormous inequality of distribution, and of all the evils that flow from it, are alike in both countries—the practical monopoly of the land and all the mineral wealth it contains by one section of the wealthy, and of what is usually termed capital by another, resulting in the monopoly by these two classes, who may both be termed capitalists, of all the products of industry and all the industrial applications of science. This arises from the fact that those who have neither land nor capital are obliged to work, at competition wages, for the capitalists, who, for the same reason, have the command of all scientific

discovery and all the inventive ability of the nation, and even of the whole civilised world. Hence it has happened that the development of steam navigation, of railroads and telegraphs, of mechanical and chemical science, and the growth of the population, while enormously increasing productive power and the amount of material products—that is, of real wealth—at least ten times faster than the growth of the population, has given that enormous increase almost wholly to one class, comprising the landlords and capitalists, leaving the actual producers of it—the industrial workers and inventors—little, if any, better off than before. If this tenfold increase of real wealth had been so distributed that *all* were equally benefited, then every worker would have had ten times as much of the necessaries and comforts of life, including a greater amount of leisure and enjoyment; while none would have starved, none would have slaved fourteen or sixteen hours a day for a bare existence; none need have had their lives shortened by unwholesome or dangerous occupations; and yet the capitalists and landlords might also have had their fair proportion of the increase. As it is, they have had many times more than their fair proportion; the result being that, if we take the whole of the class of manual labourers, little, if any, of the increase has gone to them.

A number of well-established facts proves this. In the first place, the most recent estimates of Giffen, Mulhall, and Leoni Levi, gave an average annual income of £77, or almost exactly 30s. a week, for each adult male of the working-classes. But perhaps one-third of these, including all the skilled mechanics, miners, etc., get somewhat more than this, so that the remainder must get less. Now, Mr Charles Booth puts the "margin of poverty" in London at a guinea a week per family, the test being that less than

this sum does not afford sufficient of the absolute necessaries of life—food, clothing, a sanitary dwelling, and ample firing—to keep up health and strength; and he estimates that there are in London about 1,300,000 persons who live below this margin; and, if we add to these the inmates of workhouses, prisons, hospitals, and asylums, we arrive at the fact that about *one-third* of the total population of London are living miserable, poverty-stricken lives, the bulk of them with grinding, hopeless toil, only modified by the still worse condition of want of employment, with its accompaniments of harassing anxiety and partial starvation. And this is a true picture of what exists in all our great cities and to a somewhat less degree of intensity over the whole country. There is surely very little indication here of any *improvement* in the condition of the people. Can it be maintained—has it ever been suggested—that in the early part of the century *more* than one-third of the inhabitants of London did not have sufficient of the bare necessaries of life? In order that there may have been any considerable improvement, an improvement in any degree commensurate with the vast increase of wealth, a full *half* of the entire population of London must then have lived in this condition of want and misery; and I am not aware that any writer has even suggested, much less proved, that such was the case. I believe myself that in *no* earlier period has there been such a large proportion of our population living in absolute want—below "the margin of poverty"—as at the present time; hence there has been *no* improvement in the condition of the mass of miscellaneous unskilled workers, who are now far more numerous than they ever were before. A few reasons for this belief may be given.

Since 1856 the Registrar-General has given the number of deaths in workhouses, hospitals, and other public in-

stitutions, for London, and also for England and Wales,* and in both areas the proportion of such deaths has been *increasing* for the last thirty-five years. In 1888 the Registrar-General called attention to this portentous increase, which has not yet reached its maximum. The following are the figures, in quinquennial averages, since 1870:—

DEATHS IN PUBLIC INSTITUTIONS IN LONDON

Years	Per cent. of total Deaths	Years	Per cent. of total Deaths
1861-65	... 16·2	1881-85	... 21·1
1871-75	... 17·4	1886-90	... 23·4
1876-80	... 18·6	1891-95	... 26·7

In 1861-65, the earliest five years, the proportion was 16·2 per cent. In 1892-96, the latest published, it was 26·9. And what makes this more terrible is, first, that during this period private charity had been increasing enormously; and, secondly, that almost weekly we see proofs of a growing dislike to the workhouse, so that numbers actually die of want rather than apply to the relieving officer. From 1860 to 1885 no less than 130 new charitable organisations had been established in London, and in the next ten years there were nearly 50 more. Many of these were small and local, but others embraced all London, and have continuously increased in power. Dr Barnardo's Homes, for example, beginning on a very small scale in 1866, have so increased that 5000 children who would otherwise be paupers or criminals are supported, educated, and started in life either at home or abroad. And the Church of England Society for Providing Homes for Waifs and Strays, established only in 1882, now supports

* The proportions for England and Wales are about half those for London.

about 2000 children. There are in London about 40 other institutions of similar character, each supporting from 250 to 1000 children, and 50 others with a smaller number, besides a large number of almshouses, hospitals, reformatories, homes, and charity schools. And all these institutions are constantly appealing for more funds, because they cannot keep up with the ever-increasing flood of want and misery. Then there is the large amount of relief distributed through the Charity Organisation Society, with the shelters, the farm-colony, and the extensive rescue work of the Salvation Army. And all this work of relief has been going on, and ever increasing, while the numbers of those who spend their last years and die in public institutions has also been increasing, not in numbers merely, but in proportion to the total deaths. And in the face of this overwhelming evidence of the *increase* of poverty and misery and starvation, the official apologists for things as they are, most writers for the press, and most politicians, go on declaring that pauperism is decreasing, because, by more strict rules, *out-relief* is reduced or refused altogether; while the better class of the suffering poor prefer starvation or suicide to breaking up their home, however miserable, and enduring the servitude and prison-like monotony of the workhouse.

Suicides have indeed increased most alarmingly from 1347 in 1861 to 2796 in 1895. This is for England and Wales; and the increase in proportion to the population has been from 67 per million to 92 per million. An examination of the records of inquests shows that either absolute want or the dread of want is a very frequent cause; and as the other evidence just adduced indicates the continuous increase of want, while the ever-increasing struggle in all forms of trade leads to the continual discharge of men and women who, from illness or old age,

are unable to do the same amount of work as the younger and more healthy, the two sets of facts are seen to be connected as cause and effect. If, however, poverty and unmerited want were *decreasing*, and the poor were, decade by decade, becoming *better off*, then the large and continuous increase, for more than thirty years, of deaths by suicide and in public charitable institutions, during the very same time that private charity in varied forms had increased at an altogether unprecedented rate, becomes altogether inexplicable. If poverty had heen decreasing, then we should expect the enormously increased and widespread sphere of public charity to have easily overtaken the severer forms of distress; to have reduced the deaths in the workhouse and asylum; to have diminished suicide from the dread of destitution; and to have abolished actual death from starvation in the richest and most charitable city in the world. But the facts are exactly the opposite of all this; and I submit that there is no rational explanation of them other than a continuous increase of the extremest forms of misery and want.

Illustrations of the Poverty of To-day

But these figures, proving the unequal distribution of wealth and the widespread destitution in our midst, however important and expressive to the thinker and the student, do not enable the general reader to realise their full meaning without a few concrete examples of what the poverty of to-day actually is. A few illustrative cases will therefore be given as typical of thousands and hundreds of thousands in every part of our country.

And first, let us hear what the author of the "Bitter Cry of Outcast London" had to say in 1883, the statements

in which work, though at first denied or declared to be exaggerated, were proved to be exact by the Commission of Enquiry which followed shortly after. And first as to the places in which the very poor live.

"Few who will read these pages have any conception of what the pestilential human rookeries are, where tens of thousands are crowded together amidst horrors which call to mind what we have heard of the middle passage of the slave ship. To get into them you have to penetrate courts reeking with poisonous gases arising from accumulations of sewage and refuse scattered in all directions and often flowing beneath your feet; courts, many of which the sun never penetrates, which are never visited by a breath of fresh air, and which rarely know the virtues of a drop of cleansing water. You have to ascend rotten staircases which threaten to give way beneath every step, and which in some places have already broken down. You have to grope your way along dark and filthy passages swarming with vermin. Then, if you are not driven back by the intolerable stench, you may gain admittance to the dens in which these thousands of beings, who belong as much as you to the race for whom Christ died, herd together." . . .

"Every room in these reeking tenements houses a family or two. In one room a missionary found a man ill with small-pox, his wife just recovering from her confinement, and the children running about half-naked and covered with dirt. Here are seven people living in one underground kitchen, and a little dead child lying in the same room. Here lives a widow and her six children, two of whom are ill with scarlet fever. In another nine brothers and sisters, from twenty-nine years of age downwards, live, eat, and sleep together."

And so the wretched and shameful story goes on,

and the author assures us that these are not "selected cases," but that they simply show what is to be found "in house after house, court after court, street after street"; and that the accounts are in no way exaggerated, but are often toned down, because the actual facts are too horrible to be printed.

And next, as to the work by which they live. A woman, trouser-making, can earn one shilling a day if she works *seventeen hours* at it. A woman, with a sick husband and a little child to look after, works at shirt-finishing, at 3d. a dozen, and can earn barely 6d. a day. Another maintains herself and a blind husband by making match-boxes at 2¼d. a gross, and has to pay a girl 1d. a gross to help her. Here is a mother who has pawned her four children's clothes, not for drink, but for coals and food. She obtained only a shilling, and bought seven pounds of coal and a loaf of bread! Think of the agony of distress a mother must have endured before she could do this! And the fifteen years that have passed, notwithstanding the "Royal Commission," leaves it all just as bad as before. This is what Mr Arthur Sherwell says, in his recently published "Life in West London," as to the district north of Soho, where there are more than 100,000 persons living below "the margin of poverty."

"Even under normal conditions the pressure of poverty represented by these figures is extreme; but when, as in 1895, the winter is of exceptional severity, the pressure becomes intolerable. Many of the families lived for weeks on soup and bread from the various charitable soup-kitchens in the neighbourhood. Every available article of furniture or clothing was sold or pawned; in some cases the boots were taken off the children's feet and pawned for bread or fuel. A number of families, even in the bitterest times of the long frost, lived for days without fire or light,

and often with no food but a chance morsel of bread or tea. One family had lived for weeks on bread and tea and dripping. In another room a family was found consisting of the mother and six children (the father had been in the infirmary for seven weeks), who had lived on a pennyworth of bread, a pennyworth of tea, a halfpennyworth of sugar, and a halfpennyworth of milk—*every other day*, and this was got on credit. . . . In a filthy room in another street were found several children entirely naked (this in the severest days of the long frost)! Their mother had been out since morning looking for work. Several cases were found where the family had been without food (sometimes without fire also) for three days." And while all this was going on, and in one street there were 115 adults out of work, 80 of whom had been so from one to nine months, there were, in the same district, between 7000 and 8000 paupers in the various workhouse institutions.

As one more example from a different area, we have Mrs Hogg's account of the fur-pullers of South London, in the *Nineteenth Century* of November 1897:

"The room is barely eight feet square, and it has to serve for day and night alike. Pushed into one corner is the bed, a dirty pallet tied together with string, upon which is piled a black heap of bedclothes. On one half of the table are the remains of breakfast—a crust of bread, a piece of butter, and a cracked cup, all thickly coated with the all-pervading hairs. The other half is covered with pulled skins waiting to be taken to the shop. The window is tightly closed, because such air as can find its way in from the stifling court below would force the hairs into the noses and eyes and lungs of the workers, and make life more intolerable for them than it is already. To the visitor, indeed, the choking sensation caused by the passage of the

hairs into the throat, and the nausea from the smell of the skins, is, at first, almost too overpowering for speech."

Two women work in this horrible place for twelve hours a day, and can then earn only 1s. 4d., out of which comes cost of knives and knife-grinding and fines and deductions of various kinds. In another room one woman kept herself and a daughter of nine by working all day and earning only about 7s. 6d. a week. When the work was over she was often so exhausted that she threw herself on the bed too tired even to get food. And for these poor people, of whom there are thousands, there is no hope, no future, but a life of such continuous labour, discomfort, and penury, as to be almost unimaginable to ordinary people.

The descriptions now given illustrate the horrible gulf of extreme poverty in which more than a quarter of a million of the people of London constantly live, and into which, sooner or later, are precipitated almost the whole of the million and a quarter who are permanently living below the poverty line, and to whom illness or want of work brings on absolute destitution. And we must note that none of these writers, who really know the people they write about, impute any considerable proportion of this misery to vice or drink, but to conditions over which the sufferers have no control; while it is certain that both vice and drink are very frequently the consequences of the very conditions of life they are supposed to bring about.

And for this condition of things there is absolutely no suggestion of a remedy by our legislators. Better housing has been *talked* about this twenty years, but if *done*, how would it supply work or food or coals or clothing? The very suggestion that better *houses* is the one thing needed is a cruel mockery and a confession of impotence and failure.

Dangerous and Unhealthy Trades

Equally terrible with the amount of want and misery, due mainly to insufficient earnings, want of work, or illness, is the enormous injury to health and shortening of life due to unhealthy and dangerous trades, almost all of which could be made healthy and safe if human life were estimated as of equal value with the acquisition of wealth by individuals.

In Mrs C. Mallet's tract on "Dangerous Trades for Women," we find it stated that girls who do the carding in the linen trade lose their health in about twelve years; the very strongest picked men in the alkali works as a rule do not live to be fifty; glass-blowers become prematurely old at forty, and sometimes become blind; in the potteries deaths from phthisis are three times as numerous as among other workers. But all these trades are inferior in deadliness to the white-lead manufactures, in which numbers of girls and women are employed. Some work on for several years without appreciable injury, but the majority suffer greatly in a year or two, many die in a few months, and some in a few weeks, or even days. In this trade the percentage of deaths is higher than in any other, and the real amount is never known, because, when the workers become ill, they are usually discharged. They then perhaps work for a time at some other employment, perhaps in another place, and if they ultimately die of lead-poisoning, or its consequences, their connection with the dangerous trade is lost. The children born of lead-workers usually die of convulsions, and one woman lost eight children in this way. Mr Robert Sherrard, in his "White Slaves of England," has given a later and fuller account, perfectly agreeing with Mrs Mallet's statements published three years earlier; and, notwithstanding the abuse and

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denials by interested parties, all his essential facts are fully borne out by the quotations he now gives in an appendix, from the reports of several committees, select or departmental, which have inquired into the various trades he has described, together with the evidence from coroners' inquests and other sources. Anyone who reads this appendix alone will be thoroughly convinced of the terrible amount of human suffering and of death resulting from the "dangerous trades" of England, though their total amount can never be fully realised.

And the whole of this destruction of human life and happiness is absolutely needless, since many of the products are not necessaries of life, and all, without exception, *could* be made entirely harmless if adequate pressure were brought to bear upon the manufacturers. Let every death that is clearly traceable to a dangerous trade be made manslaughter, for which the owners, or, in the case of a company, the directors, are to be punished by imprisonment, *not* as first-class misdemeanants, and ways will soon be found to carry away or utilise the noxious gases and provide automatic machinery to carry and pack the deadly white lead and bleaching powder, as would certainly be done if the owner's families or persons in their own rank of life were the only available workers.

Even more horrible than the white-lead poisoning is that by phosphorus, in the match factories. Phosphorus is not necessary to make matches, but it is a trifle cheaper and a little easier to light (and so more dangerous), and is therefore still largely used; and its effect on the workers is terrible, rotting away the jaws with the agonising pain of cancer, often followed by death. Will it be believed in future ages that this horrible and unnecessary manufacture, the evils of which were thoroughly known, was yet allowed to be carried on to the very end of the century

which claimed so many great and beneficent discoveries and prided itself on the height of civilisation it had attained? To what a depth of helplessness must the poor be brought when young girls eagerly throng to these deadly trades rather than face the struggle for food and life by other means!

And in the midst of this very pandemonium of want and suffering the rich are ever becoming more rich, and boast of it. The *City Press* tells us that the increased profits in the city of London during the ten years from 1880 to 1890 was no less than £30,755,283, and it adds: "This is the best evidence that can be furnished of our commercial prosperity." A million people in London without sufficient food and clothing and fire for a healthy life—but, great commercial prosperity! Thousands maimed or racked and tortured to death by dangerous trades—but, great commercial prosperity! Those who die paupers' deaths increasing in the ten years from 21 to 26 per cent. of the total deaths—but what of that when we have great commercial prosperity! The average lives of the lower class of artisans and workers in the unwholesome trades being only 29 years, while that of the upper classes is 55 years—millions thus killed 25 years before their time; but then we have "Great Commercial Prosperity"!

With remarkable foresight, Professor Cairnes, in 1874, wrote, that so long as the workers were dependent on the capitalists for employment "the margin for the possible improvement of their lot is confined within narrow barriers which cannot be passed, and the problem of their elevation is hopeless. As a body they will not rise at all. A few, more energetic or more fortunate than the rest, will, from time to time, escape, as they do now, from the ranks of their fellows to the higher walks of industrial life, but the great majority will remain substantially where they

are. The remuneration of labour, as such, skilled or unskilled, can never rise much above its present level." *

The result of a quarter of a century more of this dependence, though the capitalists as a class have become enormously richer, is the state of things here imperfectly depicted. And so it must remain till the workers learn what alone will save them, and take the matter into their own hands. The capitalists will consent to nothing but a few small ameliorations, which may improve the condition of select classes of workers, but will leave the great mass just where they are. For, without these thousands of struggling, starving humanity, which furnish an inexhaustible reserve of cheap labour, they believe that they cannot go on increasing their wealth; and they systematically oppose all measures which would utilise that labour for the well-being of the labourers themselves, and thus raise wages from the very bottom. This explains why they ignored Mr Mather's very moderate scheme submitted to the Select Committee on the Unemployed, as well as the far more effectual and practical scheme of Mr Herbert V. Mills, fully explained in his "Poverty and the State" nine years ago.

A few years before his much-lamented death, that acute, yet cautious, thinker, the late Professor Huxley, was forced to adopt the conclusions of Professor Cairnes and those here set forth, that our modern system of landlordism and capitalistic competition tends to increase rather than to diminish poverty; and he expressed them in one of those forcible passages which cannot be too often quoted. After declaring that in all great industrial centres there is a large and *increasing* mass of what the French call *la misère*, he goes on:

"It is a condition in which food, warmth, and clothing,

* "Some Leading Principles of Political Economy," p. 348.

which are necessary for the mere maintenance of the functions of the body in their normal state, cannot be obtained; in which men, women, and children are forced to crowd into dens where decency is abolished, and the most ordinary conditions of healthful existence are impossible of attainment; in which the pleasures within reach are reduced to brutality and drunkenness; in which the pains accumulate at compound interest in the shape of starvation, disease, stunted development, and moral degradation; in which the prospect of even steady and honest industry is a life of unsuccessful battling with hunger, rounded by a pauper's grave. . . . *When the organisation of society*, instead of mitigating this tendency, *tends to continue and intensify it*, when a given social order plainly *makes for evil and not for good*, men naturally enough begin to think it high time to try a fresh experiment. I take it to be a mere plain truth that throughout industrial Europe there is not a single large manufacturing city which is free from a large mass of people whose condition is exactly that described, and from a still greater mass who, living just on the edge of the social swamp, are liable to be precipitated into it."*

But there are yet other indications of our terribly unhealthy social condition besides poverty, misery, and preventible deaths. The first is the increase of insanity, which is certainly great, though not perhaps so large as the mere increase of the insane population. This increase from 1859 to 1889 was from 1867 per million in the former year to 2907 per million in the latter, or more than 50 per cent. faster than the population. But it is alleged that this is mainly due to the accumulation of patients owing to their being better taken care of than formerly. This, however, is only a supposition, and an improbable one,

* *Nineteenth Century*, February 1888.

since it is admitted that in our crowded asylums proper curative treatment is impossible; and the returns of the Registrar-General show that deaths in lunatic asylums are increasing faster than the number of lunatics. (In the seven years, 1888 to 1895, the deaths increased 25 per cent.) And in Chambers' "Encyclopædia" the writer who gives the above explanation also shows immediately afterwards that it only accounts for the smaller portion of the increase. He says that if we take the newly registered cases each year "we find they have only risen from 4.5 to 6 per 10,000 (or from 450 to 600 per million) in the thirty years." But this is 30 per cent. faster than the population increases; and it may therefore be taken as the admitted amount of the continuous increase of insanity among us.

Closely connected with insanity is suicide, and that this has very largely increased there is no doubt whatever, as the following table, compiled from the reports of the Registrar-General, will show:—

Years	Deaths by Suicide per Million Living
1866-70	66·4
1871-75	66·0
1876-80	73·6
1881-85	73·8
1886-90	79·4
1891-95	88·6

Dr S. A. K. Strahan, in his work on "Suicide and Insanity," states that "within certain limits the rate of suicide ebbs and flows with the prosperity of a nation," and he says that it has been *proved* by several Continental writers that the death-rate from suicide "rises and falls with the price of bread." The first statement is undoubtedly true, the latter quite untrue. During the whole

period included in the above table the price of wheat was falling from 50s. 9d. in 1859-61 to 32s. 10d. in 1889-91.

The price of bread is of no importance when the conditions of life are such that thousands of people have not the means of buying any food at all. Insanity and suicide are both largely due to want, or the dread of want, as the weekly records of coroners' inquests and the police courts plainly show.

Yet another indication of the deterioration of the people, owing to the unhealthy and unnatural conditions under which millions of them are compelled to live, is afforded by the continuous increase for the last thirty-five years of premature births and of congenital defects in those which survive. The following table, showing the proportion to 1000 births, is from the "Fifty-eighth Annual Report" of the Registrar-General, p. xviii. :—

Years	Premature Births	Congenital Defects
1861-65	11·19	1·76
1866-70	11·50	1·84
1871-75	12·60	1·85
1876-80	13·38	2·39
1881-85	14·18	3·23
1886-90	16·15	3·39
1891-95	18·42	3·87

The worst features of this table are the continuous increase it shows, indicating the action of some constant and increasing cause, and the more rapid increase in the latter half of the period, indicating that the conditions are becoming increasingly worse and worse.

It is the common belief that intemperance has greatly decreased among us, and no doubt that is the case as compared with the early part of the century. But, as

regards chronic intemperance resulting in death, the Registrar-General's figures show us that for the last thirty years it has been increasing:—

Years			Deaths from Alcoholism and Delirium Tremens per Million Living
1861-65			41·6
1866-70			35·4
1871-75	*Males*	*Females*	37·6
1876-80	60·1	24	42·2
1881-85	66·6	31	48·0
1886-90	73·6	39·2	55·4
1891-95	86·6	50·2	68·2

Here the increase began a little later, but it shows the same alarming fact of being much more rapid in the last fifteen years. For the last twenty years the deaths are given for males and females separately, and we find that the death-rates of the latter from this cause have increased with enormous rapidity. While men's deaths from intemperance have increased about 58 per cent. in the twenty years, those of women have increased more than 100 per cent. The causes that lead to this fatal amount of intoxication are various; but no one will deny that the facts here set forth show the existence of something seriously wrong in our social conditions and that the evil is rapidly increasing.

There is yet one more indication of our deterioration. One of the arguments in favour of national education was that it would certainly decrease crime. Herbert Spencer told us that it would not have that effect; that there was nothing in educating the intellect to have any effect on the amount of crime, though it might have an effect upon its character. And he seems to have been right. Owing

to changes in the classification of offenders, in the nature of their punishment, in the criminal law, and in the practice of the Courts, it is not difficult to obtain figures showing a decrease, as is often done by officials who will not readily admit that our systems of punishment have no reformatory action. But a gentleman who has had a life-long experience of prisons and prisoners, and has made a serious study of the whole subject, arrives at a different conclusion. He tells us that, after a careful examination of all available statistics for the last thirty years, and making all needful corrections for the changes above referred to, he considers it proved that crime has increased, and at a greater rate than the increase of the population for the same period. The result, which he thinks to be as near the truth as can be obtained from prison and criminal statistics, is as follows:—

Years	Prison Population	In Reformatories and Industrial Schools	Total
1860-69	127,690	6,834	134,524
1870-79	154,145	17,394	171,539
1880-89	170,827	25,505	196,332

Here we have an increase in the average of the first and last ten-year periods amounting to 46 per cent., while the increase of population in the twenty years from 1865 to 1885 is a little less than 30 per cent.*

The writer imputes this result to the continued growth of our great cities, which bring together both criminals and those who are preyed upon, and by association and opportunity foster the growth of a criminal population. To this cause, however, must be added the increasing severity

* The Rev. W. D. Morrison, late H.M. Chaplain at Wandsworth Prison, in the *Nineteenth Century*, for June 1892.

of the struggle for existence and our cruel and degrading prison system, which together render it almost impossible for first offenders to gain a livelihood by honest labour.

In concluding this brief sketch of the inevitable results of the struggle for existence and for wealth under present social conditions, I call special attention to the fact that so many converging lines of evidence point in the same direction. The evidence for the enormous increase of the total mass of misery and want is overwhelming, while that it has increased even faster than the increase of population is, to my own mind, almost equally clear. But when we see that insanity and suicide, deaths from drink, premature births, congenital defects, and the numbers of criminals have all increased simultaneously, we can hardly help seeing a relation of cause and effect, since the accidental coincidence of so many distinct phenomena is highly improbable, and the first of them—the increase of poverty, combined with dangerous or unhealthy occupations—is admitted to be a true cause, if only a contributory one, of all the rest.

But there is yet another inference to be drawn from the facts and figures which have been set forth in this chapter. If we turn to the table of death-rates in public institutions, we find that they not only increase steadily each quinquennium, but that they increase at a more rapid rate in the later than the earlier years. Dividing the period equally, we find that during the first half the death-rate increased by ·21, or rather more than a fifth, while in the second half it increased by ·26, or rather more than a fourth. And when we look at the tables showing the amount of suicides, of premature births, of congenital defects, and of deaths from alcoholism, we find that all these also show a much more rapid increase in the latter half, in-

dicating still more clearly the dependence of the latter upon the former.

Now this portentous phenomenon of the *increasing rate* of deterioration of our population is also seen in the rate of increase of individual wealth. Taking the total annual value assessed to income-tax as the best available indication of individual wealth at different periods, we find the rate of its increase during three periods of fifteen years each to be as follows:—

Years	Increase of Income-Tax Assessment
1850-65 . .	64·6 per cent. increase in 15 years.
1865-80 . .	68·6 ,, ,, ,,
1881-96 . .	82·4 ,, ,, ,,

This is for the whole of Great Britain and Ireland, and it corresponds with that recent increase of wealth in the city of London which was taken by the writer in the *City Press* to be a gratifying proof of "commercial prosperity."

Here, then, we have direct confirmation of that "increase of want with increase of wealth" which, when propounded as a fundamental fact of modern social systems in Henry George's "Progress and Poverty," was fiercely denied as utterly unfounded and the very opposite of the truth. The association of the two phenomena is clearly proved by the facts and figures here given; and that association is shown to be not a mere coincidence by the fact that not only the increase, but changes in the rate of increase, are strictly associated; and, yet further, that four separate indications of deterioration which are, partially or wholly, due to poverty, to dread of poverty, or to rapid fluctuations of wealth, also show similar changes in their rate of increase.

We have seen that, in Huxley's opinion, all the terrible social evils which have been briefly summarised in this

chapter are due to the existing *organisation of society*, and that our present social order "*makes for evil*"; the late Prof. Cairnes was of the same opinion; Frederick Harrison, in 1886, declared that the condition of the actual producers of wealth was then such as to be the condemnation of modern society,*—yet it has since then been getting worse, and all our great thinkers—prophets or poets—have condemned it. Carlyle thundered against its iniquities, but with no clear indications of a remedy; Ruskin saw more clearly that a fundamental change in our methods was necessary, and stated plainly, and I believe truly, what the first essential steps of that change must be.† Tennyson asks us:

> "Is it well that while we range with Science, glorying in the Time,
> City children soak and blacken soul and sense in city slime?"

John Stuart Mill long since warned us that when great evils are in question small remedies do not produce a small effect, but no effect at all. And Lowell says the same in his exquisite verse:

> "New occasions teach new duties: Time makes ancient good uncouth;
> They must upward still and onward, who would keep abreast of Truth;
> Lo! before us gleam her camp fires! we ourselves must Pilgrims be,
> Launch our *Mayflower*, and steer boldly through the desperate winter sea,
> Nor attempt the Future's portal with the Past's blood-rusted key."

Yet this is exactly what we *have* been doing during the whole century,—applying small plasters to each social ulcer

* *See* Report of the "Industrial Remuneration Conference," p. 429.
† *See* "Unto this Last." Preface.

as it became revealed to us—petty palliatives for chronic evils. But ever as one symptom has been got rid of new diseases have appeared, or the old have burst out elsewhere with increased virulence; and it will certainly be considered one of the most terrible and inexplicable failures of the nineteenth century that, up to its very close, neither legislators nor politicians of either of the great parties that alternately ruled the nation would acknowledge that there *could* be anything really wrong while wealth increased as it was increasing. Our ruling classes have suggested nothing, and have done nothing, of any real use. They have made fruitless inquiries into particular phases of the evils that were oppressing the workers, and have continued the application of those small remedies that always have resulted, and always must result, in no permanent benefit to the whole people. They still believe that "the Past's blood-rusted key" will open the portal of future well-being! *

* It is never my practice to condemn evils without suggesting remedies. But in this work it would be out of place to go into them in detail. I give, however, a few suggestions and references in an appendix to this volume.

CHAPTER XXIV

THE PLUNDER OF THE EARTH—CONCLUSION

"Commerce has set the mark of selfishness,
The signet of its all-enslaving power,
Upon a shining ore, and called it GOLD;
Before whose image bow the vulgar great,
The vainly rich, the miserable proud,
The mob of peasants, nobles, priests, and kings,
And with blind feelings reverence the power
That grinds them to the dust of misery."

SHELLEY.

THE struggle for wealth, and its deplorable results, as sketched in the preceding chapter, has been accompanied by a reckless destruction of the stored-up products of nature, which is even more deplorable because more irretrievable. Not only have forest-growths of many hundreds of years been cleared away, often with disastrous consequences, but the whole of the mineral treasures of the earth's surface, the slow products of long past eons of time and geological change, have been and are still being exhausted, to an extent never before approached, and probably not equalled in amount during the whole preceding period of human history.

In our own country the value of the coal exported to foreign countries has increased from about £3,000,000 to more than £16,000,000 sterling per annum, the quantity being now about 30,000,000 tons; and this continuous exhaustion of one of the necessaries of existence is wholly in the interest of landlords and capitalists, while millions of our people have not sufficient for the ordinary

needs or comforts of life, and even die in large numbers for want of the vital warmth which it would supply. Another large quantity of coal is consumed in the manufacture of iron for export, which amounts now to about 2,000,000 tons per annum. A rational organisation of society would ensure an ample supply of coal to every family in the country before permitting any export whatever; while, if our social organisation was both moral and rational, two considerations would prevent any export: the first being that we have duties towards posterity, and have no right to diminish unnecessarily those natural products which cannot be reproduced; and the second, that the operations of coal-mining and iron-working being especially hard and unpleasant to the workers, and at the same time leading to injury to much fertile land and natural beauty, they should be restricted within the narrowest limits consistent with our own wellbeing.

In America and some other countries an equally wasteful and needless expenditure of petroleum oils and natural gas is going on, resulting in great accumulations of private wealth, but not sensibly ameliorating the condition of the people at large. Such an excellent light as that afforded by petroleum oil is no doubt a good thing; but it comes in the second grade as a comfort, not a necessity, and it is really out of place till everyone can obtain ample food, clothing, warmth, house room, and pure air and water, which are the absolute *necessaries* of life, but which, under the conditions of our modern civilisation—more correctly barbarism—millions of people, through no fault of their own, cannot obtain. In these respects we are as the scribes and pharisees, giving tithe of mint and cummin, but neglecting the weightier matters of the law.

Equally disastrous in many respects has been the wild struggle for gold in California, Australia, South Africa,

and elsewhere. The results are hardly less terrible, though in different ways, than those produced by the Spaniards in Mexico and Peru four centuries ago. Great wealth has been obtained, great populations have grown up and are growing up; but great cities have also grown up with their inevitable poverty, vice, overcrowding, and even starvation, as in the old world. Everywhere, too, this rush for wealth has led to deterioration of land and of natural beauty by covering up the surface with refuse heaps, by flooding rich lowlands with the barren mud produced by hydraulic mining, and by the great demand for animal food by the mining populations, leading to the destruction of natural pastures in California, Australia, and South Africa, and their replacement often by weeds and plants neither beautiful nor good for fodder.

It is also a well-known fact that these accumulations of gold-seekers lead to enormous social evils, opening a field for criminals of every type, and producing an amount of drink-consumption, gambling, and homicide altogether unprecedented. Both the earlier gold-digging by individual miners and the later quartz-mining by great companies are alike forms of gambling or speculation; and while immense fortunes are made by some, others suffer great losses, so that the gambling spirit is still further encouraged, and the production of real wealth by patient industry to the same extent diminished and rendered less attractive. For it must never be forgotten that the whole enormous amount of human labour expended in the search for and the production of gold; the ships which carry out the thousands of explorers, diggers, and speculators; the tools, implements, and machinery they use; their houses, food, and clothing, as well as the countless gallons of liquor of various qualities which they consume, are all, so far as the wellbeing of the community is concerned, absolutely

wasted. Gold is *not* wealth; it is neither a necessary nor a luxury of life in the true sense of the word. It serves two purposes only: it is an instrument used for the exchange of commodities, and its use in the arts is mainly as ornament or as an indication of wealth. Nothing is more certain than that the appearance of wealth produced by large gold-production is delusive. The larger the proportion of the population of a country that devotes itself to gold-production the smaller the numbers left to produce real wealth—food, clothing, houses, fuel, roads, machinery, and all the innumerable conveniences, comforts, and wholesome luxuries of life. Hence, whatever appearances may indicate, gold-production makes a country poor, and by furnishing new means of investment and speculation helps to keep it poor; and it has certainly helped considerably in producing that amount of wretchedness, starvation, and crime which, as we have seen, has gone on increasing to the very end of the century.

But the extraction of the mineral products stored in the earth in order to increase individual wealth, while at the same time diminishing national wellbeing, is only a portion of the injury done to posterity by the "plunder of the earth." In tropical countries many valuable products can be cultivated by means of cheap native labour so as to give a large profit to the European planter. But here, also, the desire to get rich as quickly as possible has often defeated the planter's hopes. Nutmegs were grown for some years in Singapore and Penang; but by the exposure of the young trees to the sun, instead of growing them under the shade of great forest trees, as in their natural state and as they are grown in Banda, they became unhealthy and unprofitable. Then coffee was planted, and was grown very largely in Ceylon and other places; but here again the virgin forests were entirely removed,

producing unnatural conditions, and the growth of the young trees was stimulated by manure. Soon there came disease and insect enemies, and coffee had to be given up in favour of tea, which is now grown over large areas both in Ceylon and India. But the clearing of the forests on steep hill slopes to make coffee plantations produced permanent injury to the country of a very serious kind. The rich soil, the product of thousands of years of slow decomposition of the rock, fertilised by the humus formed from decaying forest trees, being no longer protected by the covering of dense vegetation, was quickly washed away by the tropical rains, leaving great areas of bare rock or furrowed clay, absolutely sterile, and which will probably not regain its former fertility for hundreds, perhaps thousands, of years. The devastation caused by the great despots of the middle ages and of antiquity, for purposes of conquest or of punishment, has thus been reproduced in our times by the rush to obtain wealth.

Even the lust of conquest, in order to secure slaves and tribute and great estates, by means of which the ruling classes could live in boundless luxury, so characteristic of the early civilisations, is reproduced in our own time. The last years of the century witnessed the struggle of the great Powers of Europe in order to divide up the whole continent of Africa among themselves and thus obtain an outlet for the more energetic portions of their populations and an extension of their trade. The result, so far, has been the sale of vast quantities of rum and gunpowder; much bloodshed, owing to the objection of the natives to the seizure of their lands and their cattle; great demoralisation both of black and white; and the condemnation of the conquered tribes to a modified form of slavery. Comparing our conduct with that of the Spanish conquerors of the West Indies, Mexico, and Peru, and making some allowance for differences of race and of public opinion,

there is not much to choose between them. Wealth and territory and native labour were the real objects of the conquest in both cases; and if the Spaniards were more cruel by nature, and more reckless in their methods, the results were much the same. In both cases the country was conquered, and thereafter occupied and governed by the conquerors frankly for their own ends, and with little regard to the feelings or the material wellbeing of the conquered. If the Spaniards exterminated the natives of the West Indies, we have done the same thing in Tasmania, and almost the same in temperate Australia. And in the estimation of the historian of the future, the Spaniards will be credited with two points in which they surpassed us. Their belief that they were really serving God in converting the heathen, even at the point of the sword, was a genuine belief shared by priests and conquerors alike—not a mere sham, as is ours when we defend our conduct by the plea of introducing the "blessings of civilisation." And, in wild romance, boldness of conception, reckless daring, and the successful achievement of the well-nigh impossible, we are nowhere when compared with Cortez and his five hundred Spaniards, who, with no base of supplies, no rapid steam communication, no supports, imperfect weapons, and the ammunition they carried with them, conquered great, populous, and civilised empires. It is quite possible that both the conquest of Mexico and Peru by the Spaniards, and our conquest of South Africa, may have been real steps in advance, essential to human progress, and helping on the future reign of true civilisation and the wellbeing of the human race. But if so, we have been, and are, unconscious agents in hastening that great

> "far-off, divine event
> To which the whole creation moves."

We deserve no credit for it. Our aims have been, for the most part, sordid and selfish; and if, in the end, all should work out for good, as no doubt it will, much of our conduct in the matter will yet deserve, and will certainly receive, the severest condemnation.

Our whole dealings with subject races has been a strange mixture of good and evil, of success and failure, due, I believe, to the fact that, along with a genuine desire to do good and to govern well, our rule has always been largely influenced, and often entirely directed, by the necessity of finding well-paid places for the less wealthy members of our aristocracy, and also by the constant craving for fresh markets by the influential class of merchants and manufacturers. Hence the enormous fiscal burdens under which the natives of our Indian Empire continue to groan; hence the opium monopoly and the salt tax; hence the continued refusal to carry out the promises made or implied on the establishment of the Indian Empire, to give the natives a continually increasing share in their own government, and to govern India solely in the interest of the Indians themselves.

It is the influence of the two classes above referred to that has urged our governments to perpetual frontier wars, and continual extensions of the Empire, all adding to the burdens of the Indian people. But our greatest mistakes of all are the collection of revenue in money at fixed times from the very poorest cultivators of the soil, and the strict enforcement of our laws relating to landed property, to loans, mortgages, and foreclosures, which are utterly unsuited to the people, and have led to the most cruel oppression and the transfer of numbers of small farms from the ryots to the money-lenders. Hence the peasants become poorer and poorer; thousands have been made tenants instead of owners of their farms; and an immense

number are in the clutches of the money-lenders and always in the most extreme poverty. It is from these various causes that the periodical famines are so dreadful a scourge and such a disgrace to our rule.* The people of India are industrious, patient, and frugal in the highest degree; and the soil and climate are such that the one thing wanted to ensure good crops and abundance of food is water-storage for irrigation and absolute permanence of tenure for the cultivator. That we have built costly railways for the benefit of merchants and capitalists, and have spent upon these and upon frontier wars the money which would have secured water for irrigation wherever wanted, and thus prevented the continued recurrence of famine whenever the rains are deficient, is an evil attendant on our rule which outweighs many of its benefits.

The final and absolute test of good government is the wellbeing and contentment of the people—*not* the extent of empire or the abundance of the revenue and the trade. Tried by this test, how seldom have we succeeded in ruling subject peoples! Rebellion, recurrent famines, and plague in India; discontent, chronic want, and misery; famines more or less severe, and continuous depopulation in our sister-island at home—these must surely be reckoned among

* These facts, together with our most cruel and wicked robbery of the rayats, or cultivators, constituting three-fourths of the entire population, by changing the *land-tax* to a *rack-rent* as exorbitant and impossible of payment as those of the worst Irish and Highland landlords, have been long known, and have been again and again urged by the most experienced Indian administrators as the fundamental cause of all Indian (as they are of all Irish) famines. But, quite recently, they have been again described, with admirable lucidity and almost unnecessary moderation, by Sir William Wedderburn, whose great experience in India as a district judge, and long study of the subject, constitute him one of the first authorities. See a series of articles in the periodical *India* for February, March, May, and June 1897. A reprint of the whole under the very appropriate title—"The Skeleton at the (Jubilee) Feast," has been sent to all members of the House of Commons; and they should be read by everyone who wishes to comprehend the terrible misgovernment of our Indian Empire.

the most terrible and most disastrous failures of the nineteenth century.

> "Hear then, ye Senates! hear this truth sublime,
> They who allow Oppression share the crime."

Concluding Remarks

We are now in a position to form some general estimate of progress and retrogression during the nineteenth century, and to realise to some extent what will be the verdict of the future upon it. We have seen that it has been characterised by a marvellous and altogether unprecedented progress in knowledge of the universe and of its complex forces; and also in the application of that knowledge to an infinite variety of purposes, calculated, if properly utilised, to supply all the wants of every human being, and to add greatly to the comforts, the enjoyments, and the refinements of life. The bounds of human knowledge have been so far extended that new vistas have opened to us in directions where it had been thought that we could never penetrate, and the more we learn the more we seem capable of learning in the ever-widening expanse of the universe. It may be truly said of men of science that they have now become as gods knowing good and evil, since they have been able not only to utilise the most recondite powers of nature in their service, but have, in many cases, been able to discover the sources of much of the evil that afflicts humanity, to abolish pain, to lengthen life, and to add immensely to the intellectual as well as to the physical enjoyments of our race.

But the more we realise the vast possibilities of human welfare which science has given us, the more we must recognise our total failure to make any adequate rational use of them. With ample power to supply to the fullest

extent necessaries, comforts, and even luxuries for all, and at the same time allow ample leisure for intellectual pleasures and æsthetic enjoyments, we have yet so sinfully mismanaged our social economy as to give unprecedented and injurious luxury to the few, while millions are compelled to suffer a lifelong deficiency of the barest necessaries for a healthy existence. Instead of devoting the highest powers of our greatest men to remedy these evils, we see the governments of the most advanced nations arming their people to the teeth, and expending much of their wealth and all the resources of their science in preparation for the destruction of life, of property, and of happiness.

With ample knowledge of the sources of health, we allow, and even compel, the bulk of our population to live and work under conditions which greatly shorten life; while every year we see from 50,000 to 100,000 infants done to death by our criminal neglect.

In our mad race for wealth we have made gold more sacred than human life; we have made life so hard for the many that suicide and insanity and crime are alike increasing. With all our labour-saving machinery and all our command over the forces of nature, the struggle for existence has become more fierce than ever before; and year by year an ever-increasing proportion of our people sink into paupers' graves.

Even more degrading, and more terrible in its consequences, is the unblushing selfishness of the greatest civilised nations. While boasting of their military power, and loudly proclaiming their Christianity, not one of them has raised a finger to save a Christian people, the remnant of an ancient civilisation, from the most barbarous persecution, torture, and wholesale massacre. A hundred thousand Armenians murdered or starved to death while the representatives of the great Powers coldly looked on—

and prided themselves on their unanimity in all making the same useless protests—will surely be referred to by the historian of the future as the most detestable combination of hypocrisy and inhumanity that the world has yet produced, and as the crowning proof of the utter rottenness of the boasted civilisation of the nineteenth century.

When the brightness of future ages shall have dimmed the glamour of our material progress, the judgment of history will surely be that the ethical standard of our rulers was a deplorably low one, and that we were unworthy to possess the great and beneficent powers that science had placed in our hands.

But although the past century gave us so many examples of failure, it has also given us hope for the future. True humanity; the determination that the crying social evils of our time shall *not* continue; the certainty that they *can* be abolished; an unwavering faith in human nature, have never been so strong, so vigorous, so rapidly growing as they are to-day. The movement towards Socialism during the last ten years, in all the chief countries of Europe as well as in America, is the proof of this. This movement pervades the rising generation as much in the higher and best educated section of the middle-class as in the ranks of the workers. The people are being educated to understand the real causes of the social evils that now injure all classes alike and render many of the advances of science curses instead of blessings. An equal rate of such educational progress for another quarter of a century will give them at once the power and the knowledge required to initiate the needed reforms.

The flowing tide is with us. We have great poets, great writers, great thinkers, to cheer and guide us; and

an ever-increasing band of earnest workers to spread the light and help on the good time coming. And as the last century has witnessed a material and intellectual advance wholly unprecedented in the history of human progress, so the dawning century will reap the full fruition of that advance in a moral and social upheaval of an equally new and unprecedented kind, and equally great in amount. That advance is prefigured in the stirring lines of Sir Lewis Morris, with which I may fitly close my work:

> "There shall come, from out this noise of strife and groaning,
>   A broader and a juster brotherhood,
> A deep equality of aim, postponing
>   All selfish seeking to the general good.
> There shall come a time when each shall to another,
> Be as Christ would have him, brother unto brother.
>
> "There shall come a time when brotherhood shows stronger
>   Than the narrow bounds which now distract the world;
> When the cannons roar and trumpets blare no longer,
>   And the ironclad rusts and battle-flags are furled;
> When the bars of creed and speech and race, which sever,
> Shall be fused in one humanity for ever."

APPENDIX

THE REMEDY FOR WANT IN THE MIDST OF WEALTH

"The end of Government is to unfold
The Social into harmony, and give
Complete expression to the labouring thought
Of universal genius; first to feed
The body, then the mind, and then the heart."

T. L. HARRIS.

"New Times demand new measures and new men;
The world advances, and in time outgrows
The laws that in our fathers' days were best."

LOWELL

THE experience of the whole century, and more especially of the latter half of it, has fully established the fact that, under our present competitive system of capitalistic production and distribution, the continuous increase of wealth in the possession of the capitalist and landowning classes is *not* accompanied by any corresponding diminution in the severity of misery and want or in the numbers of those who suffer from extreme poverty, rendered more unendurable by the presence of the most lavish waste and luxury on every side of them. Even the most cautious writers who really look at the *facts* are compelled to admit so much as this; but, as I have shown, the actual facts prove more than this. They show clearly that with the increase of wealth there has been a positive and very large *increase* of want; while if we take account of *all* the facts and without prejudice or prepossession consider what they really imply, we are driven to the conclusion that, during the latter half of the most marvellous of all the centuries, while science has been enlarging man's power over nature

in a hundred varied ways, resulting in possibilities of wealth-production a hundred-fold that of any preceding century, the direst want of the bare necessaries of life has seized upon, not only a greater absolute number, but a larger proportion of our population; and this has happened notwithstanding an increase of charity and benevolent work among the poor which is equally unexampled.

Many of our greatest writers and clearest thinkers have observed these facts, and have plainly declared that our social system has broken down. The number of those who see this is increasing daily; and the public conscience is being aroused by the heartrending misery and suffering of millions of those who work, or beg to be allowed to work, in order to produce comforts and luxuries for others while living in poverty, hunger, and dirt themselves. I take it for granted that we shall not much longer permit this social hell to surround us on every side without making some strenuous efforts to abolish it. To do this with the slightest chance of success we must recognise the absolute inefficiency of the old methods of charity and other small ameliorations, except as admittedly temporary measures; and we must devote ourselves to work on new lines which must be fundamental in their nature and calculated to remove the *causes* of poverty.

I have myself indicated those lines in an address to the Land Nationalisation Society in 1895, reprinted with alterations and addition in "Forecasts of the Coming Century," of which it forms the first article, under the title "Reoccupation of the Land," and again (by permission) in my "Studies Scientific and Social," vol. ii. chap. xxvi. The principle is, briefly, the Organisation of Labour, in Production, *for the Consumption of the Labourers.* Nobody has attempted, seriously, to show why this should not be done. Even if the land and stock necessary to start each such co-operative colony were given free, it would be the wisest and most profitable public expenditure ever made, because it is certain to abolish all unmerited poverty by absorbing *all the unemployed.* I have shown by sufficient examples the enormous economies of

such organisation of labour—economies so great, and acting in so many directions, that it is quite certain to result, not only in a subsistence for the workers, but in an abundance of all the necessaries, comforts, and rational enjoyments of life.

Just consider for a moment. The workers of the country, very imperfectly organised by the capitalists in their own interests, *do* actually produce every year all the wealth that is consumed, including not only necessaries and comforts, but an enormous quantity of luxuries consumed only by the wealthy. All these workers when in full work *do* earn enough to live on, and many of them to live comfortably, although they are paid less than half, often only a quarter, of the value of their work in the finished article. It is only because the value they add to the product is many times more than the wages they receive that there is a surplus sufficient to give a profit to the capitalist-manufacturer and to two or three middlemen, to pay for railway carriage, for travellers, and for advertisements, as well as for loss upon unsaleable goods. *All* these expenses would be saved when almost everything was made to be consumed on the spot by the producers themselves, only a few surplus products being sold in the nearest market to pay for some foreign luxuries. How could such an organisation fail to succeed? If it is said that the unemployed are not first-rate workmen, we reply second or even third-rate men will do very well. Average mechanics—carpenters, masons, plumbers, tanners, tailors, shoemakers, spinners, weavers, agricultural labourers, etc. —will be able to build second-class houses, make second-class clothing, and produce plain food. Again, why not? If every kind of trade and manufacture can be carried on and well managed by public companies, whose shareholders know nothing of the business, why not by the local authorities? Every company has to compete with other companies and with great capitalists in the *sale* of its products. Here there would be no competition, as the great bulk of the products would be consumed by the

producers themselves, and in some cases exchanged for the products of other similar settlements when it is found to be beneficial to do so. Why, then, is this not done? Why is it nowhere attempted? There is really only one answer: Manufacturers and capitalists *are afraid it would succeed.* They *know*, in fact, that it would succeed only too well; that it would render those who are now unemployed self-supporting; and, by abolishing the spur of starvation, or the dread of starvation, would raise wages all round. Hence, so long as we have capitalist governments, and the workers are so blind as to send manufacturers and capitalists, landlords and lawyers to misrepresent them in Parliament, a really effective remedy will *not* be tried.

But will advanced thinkers and the educated workers continue much longer to permit myriads to suffer penury that a few may get rich? for that is really what it comes to. The mere consideration that the powers of production are now practically unlimited, and that not only enough for every human being but far more than could possibly be consumed can be produced by the machinery and labour now in existence, shows how cruel and unnecessary is the system that condemns so many men and women and children either to long hours of grinding labour or to enforced idleness and its attendant want and misery.

The ingenious sophistries of modern writers, from the point of view of the competitive and capitalistic system as an absolute fundamental fact, have rendered it difficult for most people to comprehend the reason of the paradox that with an enormous increase of wealth and of power of producing all commodities there should be a corresponding perpetuation or even increase of poverty. We owe it to an American writer to have cleared up this difficulty more completely and more intelligibly than has ever been done before; and I strongly recommend those who wish to understand how it is that our capitalistic individualism *necessarily* produces and perpetuates poverty to read Chapter xxii. of Mr Edward Bellamy's new book, "Equality," entitled: "Economic Suicide of the Profit System."

Although the form of this chapter is not perhaps the best, being that of a school examination, it is, nevertheless, an admirably reasoned discussion of the problem, and is, in my judgment, absolutely conclusive. Chapter xxvi. extends the discussion to the effects of foreign trade, both free and protectionist, and shows that under our capitalist and competitive system this only further intensifies the evil as regards the poverty of the masses. Another chapter (xxiii.), entitled "The Parable of the Water Tank," is an amusing illustration of the absurdity of our system, in which a superabundance of all the necessaries of life produced by the labour of the people actually increases the want and starvation of the same people!

Seeing, then, that the *actual facts* of the case at the end of a century of ever-increasing capacity of wealth-production are in complete accordance with its *necessary results* logically reasoned out from the premises of competitive capitalism, we are bound, as rational beings, to get rid of this system with as little disturbance as possible, and, therefore, by some process of evolution; but, nevertheless, in such a way as at once to remedy its most cruel and disgraceful effects. The method I have suggested is one of the least revolutionary, while it is, I believe, the easiest and the most effective; and during its gradual extension experience will be gained as to the best methods of carrying it out over the whole country.

How to stop Starvation while the Permanent Remedy is being organised

But till some such method is demanded by public opinion, and forced upon our legislators, the horrible scandal and crime of men, women, and little children, by thousands and millions, living in the most wretched want, dying of actual starvation, or driven to suicide by the dread of it—MUST BE STOPPED! I will therefore conclude with suggestions for stopping this horror *at once*; and also for obtaining the

necessary funds, both for this *temporary* purpose and to carry out the system of co-operative colonies already referred to.

The only certain automatic way to abolish starvation, not when it is too late but in its very earliest stages, is *free bread.* I imagine the outcry against this—"pauperisation! fraud! loafing!" etc. etc. Perhaps so; perhaps not. But if it *must* be so, better a hundred loafers than a thousand starving; and if my main proposal or something equally effective is adopted, the loafers will soon be disposed of. I have thought over this plan of free bread for several years, and I now believe that all the difficulties may be easily overcome. In the first place, *all* who want it, all who have not money to buy wholesome food, must be enabled to get this bread with the minimum of trouble. There must be no *tests* like those for poor-law relief. A decent home with good furniture and good clothes must be no bar; neither must the possession of money, if that money is required for rent, for coals, or for any other necessaries of life. The bread must be given to *prevent* injurious penury, not merely to alleviate it. Whenever a man (or woman) is out of work from no fault of his own, however good wages he earns when in work, he must have a claim to bread. The bread is *not* to be charity, *not* poor-relief, but a rightful claim upon society for its neglect to so organise itself that *all*, without exception, who have worked, and are willing to work, or unable to work, may at the very least have food to support life.

Now for the mode of obtaining this bread. All local authorities shall be required to prepare bread-tickets duly stamped and numbered, of a convenient form, with coupons to be detached, each representing a 4-lb. loaf. These tickets are to be issued in suitable quantities to every policeman, to all the clergy of every denomination, to all medical men, and to such other persons as may be willing to undertake their distribution and are considered to be trustworthy. Any person in want of food, on applying to any of these distributors, is to be given a coupon for one loaf (initialled or signed by the giver) *without any question*

whatever. If the person wants more than one loaf, or wishes to have more than one loaf a day for a week or a month, he or she must give name and address. The distributer, or some deputy, will then pay a visit during the day, ascertain the facts, give a suitable number of bread-tickets, and, if needful, as in case of sickness or delicate health, obtain further relief from charitable persons or from any funds available for the purpose.

Now, there are only two possible objections to this method of *temporarily* stopping starvation while more permanent measures are preparing. The first is, that it would pauperise; the next, that, as wages tend to sink to the minimum for bare subsistence, it would still further lower wages, so that it would then become needful to give coals free, and a little later rent free, till wages were reduced to the Scriptural penny a day and the whole of the unskilled workers had to be supported. The first objection is absurd; because the effect of this free bread would be to check and almost abolish pauperisation. It would enable the home to be kept up; it would prevent that cruel mockery of the present poor-law system that the home must be denuded or given up, the children's clothes pawned, all self-respect lost, *before* relief is given. The second objection, if valid, would be the strongest condemnation of our actual competitive wage system. But it is not valid. It is the pressure of absolute hunger, of the still more cruel pang of seeing their children pining for want of bread, that makes men and women consent to work for anything they can get, and gives all the power to the sweater's trade. The being able to hold out a week or a month would give strength to the poor half-starved women and children now working their lives out in misery and destitution. It would give them power and time to bargain. In each shop or factory they could combine. They could *afford to strike* against oppression, which they dare not do now, and the result would be a rise, not a fall of wages. But, for some persons, that will be an equal objection; and as no one can tell *exactly* what

would happen, except that *starvation would be abolished,* perhaps it is simpler to ignore all such theoretical and imaginary evils. Let us first stop the starvation, and leave other difficulties to be dealt with as they arise.

Another, and perhaps a better, method of dealing with destitution under our present social system is that described by Miss Sutter in her most interesting book "Cities and Citizens" as practised to-day in many German cities. But it is generally admitted that this is impracticable in Britain owing to the greater struggle for wealth; and in the mean-time starvation *must* be abolished.

How to get the Funds.—This question ought not to require asking in a country where there is such enormous accumulated wealth in the hands of individuals that a large part of it is absolutely useless to them, gives them no rational pleasure, and is, really and fundamentally, the *cause* of the very poverty we seek to abolish.

There are now in Great Britain sixty-six persons whose incomes from "trades and professions" are £50,000 a year and upwards. The total amount of the sixty-six incomes is £5,632,577, so that the *surplus*, over £50,000 a year each, amounts to £2,332,577 a year. Up to the end of the eighteenth century it is probable that no one person in Great Britain had an income of £50,000 a year. It would then have been considered what Dr Johnson termed "wealth beyond the dreams of avarice," and even to-day it is far beyond what is sufficient for every luxury which one family ought to have or ought to want. Surely, for the one purpose of giving BREAD to those who need it, to save MILLIONS from insufficiency of food culminating in absolute starvation, there can be few of these sixty-six who, when appealed to by the humanity, by the intellect, and by the religion of the nation, will refuse to give up this enormous superfluity of wealth to the bread fund, to be taken charge of, perhaps, by the Local Government Board, and administered, on the principles here suggested, by the local authorities. For those who refuse there will be the scorn and contempt of all good men. In the burning words of Scott:

> "High though his titles, proud his name,
> Boundless his wealth as wish can claim,
> Despite those titles, power, and pelf,
> The wretch, concentred all in self,
> Living, shall forfeit fair renown,
> And, doubly dying, shall go down
> To the vile dust from whence he sprung,
> Unwept, unhonoured, and unsung."

But the above-named amount is only a part, a very small part, of the wealth that is immediately available. There are sitting in the House of Lords sixty peers who hold possession of land producing a rental of over £50,000 a year each. The sum total of these sixty rentals is £5,405,900, so that the amount of the surplus is £2,405,000 a year, and as the average rental is something over a pound an acre, this surplus represents considerably more than 2,000,000 acres of land. The owners of this surplus land should also be invited to make it over to the nation, to be used, temporarily, for the bread fund, but ultimately for the establishment of the co-operative colonies. Surely these sixty noble lords will not refuse, from their great superfluity, to return a portion to the nation for the use of those workers who give to the land all its rental value!

But these two surplus revenues, amounting to more than four and a half millions a year, are over and above the enormous revenues derived from the great London estates. Some of these would be wholly available as surplus, since their owners possess incomes of £50,000 a year from other sources; while in other cases the total income would be brought to a higher amount than £50,000 by the addition of the London property. There is thus available a fund of at least £6,000,000 or £7,000,000 a year, without reducing any rich man's income below £50,000 a year.

But we should not wish to shut out from this great act of restitution to the nation those persons who possess the comparatively moderate wealth of from £10,000 a year upwards, who might be invited to contribute 10 per cent., 20 per cent., 30 per cent., or 40 per cent. of their surplus

over the same number of thousands in their income; and this would certainly produce another million or two million per annum, as there are over a thousand persons in this class with an average income of about £18,000 per annum.

It is estimated that two pounds of bread a day is a full average for the consumption per head, even if no other food is available. The cost of this at 5d. the 4-lb. loaf would be £3, 16s. a year, so that to supply a million people the *whole year* would require £3,800,000. This might be enough, or there might be a demand for double this; but the very fact of there being so large a want of mere bread would incite to the adoption of permanent means by which *all* could be rendered at least self-supporting; and for this purpose the 2,000,000 acres of land would be at once available as a beginning.

It will probably be objected that *none* of these millionaires will give up their surplus wealth, however piteously we may appeal to them in the name of the suffering millions, from whose labour every pound has been derived, and without whose labour they themselves would be reduced to destitution. Perhaps it may be so. But, if so it be, the people will know the characters of those whom they have to deal with, and will be driven to use their power as voters to obtain by the forms of law what they have not been able to obtain by appeals to either the mercy or the justice of these rich men—who, while calling themselves Christians, will not part with their superfluity of gold and land even to give bread to the poor and needy, and to save widows and the fatherless from misery and starvation.

The means to do this is plain. They must vote for no candidate who will not promise to support, first, a progressive income-tax on that portion of all incomes above £10,000, rising to 100 per cent. on the surplus above £50,000, as here suggested; and, secondly, to support a corresponding or even larger increase in the death duties. The law now permits a man to disinherit his children, or other legal heirs, whenever he chooses; and in thus

permitting him recognises the important principle that *no one has an indefeasible claim to succeed to any property whatever!* For great public purposes, therefore, the State may justly declare itself the heir to any proportion of the property, or even to the whole property, of deceased persons. But the State would at the same time recognise the duty—which the owner of property does not always recognise—of providing for all persons dependent on the deceased, either by means of an ample annuity for those past middle life, or by a suitable education and start in life for younger relatives or dependants, and for children.

In this way ample funds would be available for the various purposes here suggested, without really injuring anyone. These purposes — the abolition of starvation, penury, and the degraded life of millions—are the greatest and most important which any government can undertake, and should, *now*, constitute its first duty. They are the essential first step to any really effective social advance; and if all earnest reformers of every class would unite their forces their efforts would soon be crowned with success. I have done what I can to prove the utter breakdown of our present state of social disorganisation—a state which causes all the advances in science and in our command over the forces of nature to be absolutely powerless to check the growth of poverty in our midst. Every attempt to salve or to hide our social ulcers has failed, and must continue to fail, because those ulcers are the necessary product of competitive individualism.

I therefore call upon all earnest and thinking men and women to devote their energies to advocating those more fundamental changes which both theory and experience prove to be needed, and which alone have any chance of success.

Since this book was first issued another proposal of a fundamental reform of our social system—and perhaps the best of all—has been made by Mr John Richardson, a civil engineer, in his remarkable little work, "The Education Problem and its Solution" (published by the Twentieth

Century Press, 37A Clerkenwell Green). I strongly urge all my readers to obtain and study this most admirable little work —a true work of genius, and at the same time most severely practical. The production of such works as this, as well as that of Miss Sutter already referred to, gives us renewed hope for humanity.

"For now—thought oft mistaken, oft despairing,
At last, methinks, at last I see the dawn ;
At last, though yet a-faint, the awakening nations
Proclaim the passing of the night forlorn ;
Soon shall the long-conceivèd child of Time
Be born of Progress—soon the morn sublime
Shall burst effulgent through the clouds of Earth,
And light Time's greatest page—O Right, thy glorious birth !"

J. H. DELL.

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