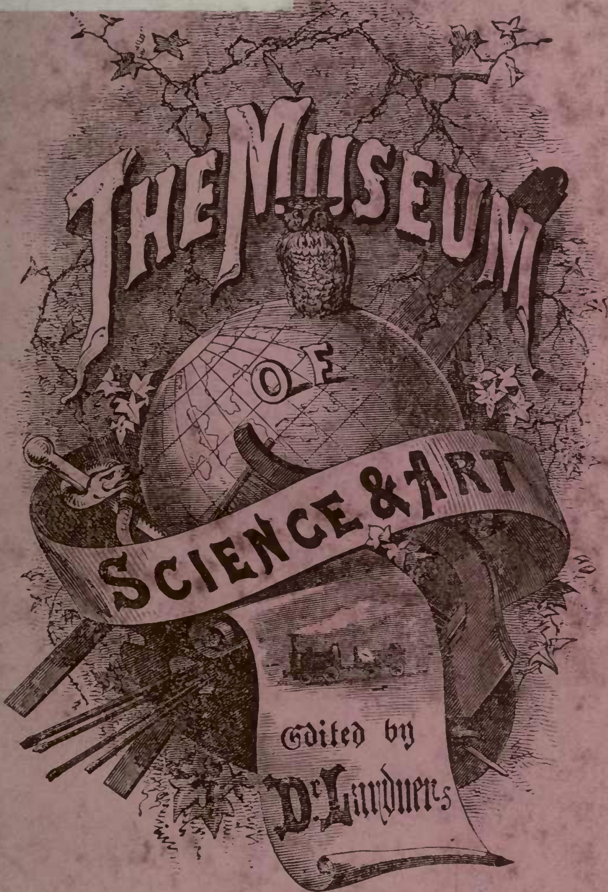
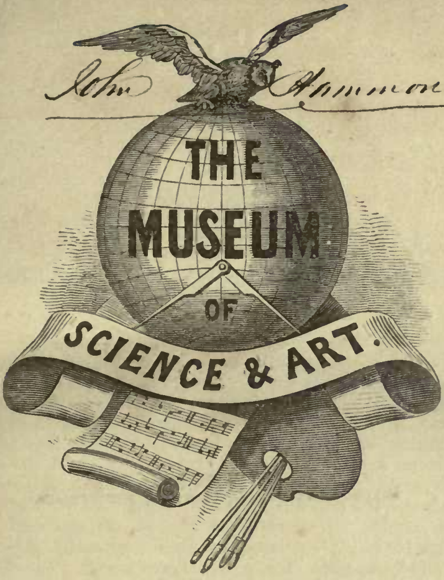



LONDON
WALTON AND MABERLY,
UPPER GOWER STREET & IVY LANE.

Price Eighteenpence.

John Hammond




EDITED BY

DIONYSIUS LARDNER, D.C.L.,

Formerly Professor of Natural Philosophy and Astronomy in University College, London.

ILLUSTRATED BY ENGRAVINGS ON WOOD.

VOL. III.

LONDON:
WALTON AND MABERLY,
UPPER GOWER STREET AND IVY LANE, PATERNOSTER ROW.
1854.

LOAN STACK

LONDON:
BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

# CONTENTS.

## LOCOMOTION AND TRANSPORT, THEIR INFLUENCE AND PROGRESS.

PAGE

CHAP. I. INFLUENCE OF IMPROVED TRANSPORT ON CIVILISATION.—1. Art of transport essential to social advancement.—2. Its rapid advancement in modern times.—3. Commerce mainly dependent on it.—4. Its conditions.—5. Its advantages, its influence on price.—6. Example of cotton.—7. Agricultural products.—8. Reciprocal advantages to rural and urban population.—9. Absence of good means of transport injurious to France.—10. Renders worthless or injurious articles serviceable and valuable.—11. Stimulates both production and consumption.—12. Increases the demand for labour.—13. Effects of railways.—14. Advantages of increased speed.—15. In the transport of cattle.—16. Steam vessels not so well adapted to this.—17. Supply of milk to towns.—18. Advantages to farmers and landlords.—19. Advantages of steam navigation.—20. Advantages of personal locomotion.—21. In the case of the working population.—22. Influence on the value of land.—23. Advantages to the population of large cities.—24. Relative speed of horse coaches and railways.—25. Military advantages.—26. Offers inducements to peace and the means of abridging war.—27. Influence on the diffusion of knowledge.—28. The electric telegraph.—29. Journalism . . . . . . . . . 1

CHAP. II. RETROSPECT OF THE PROGRESS OF TRANSPORT.—1. Of the first construction and improvement of roads and carriages.—2. Roads do not exist in more than two-sevenths of the inhabited parts of the globe.—3. Roman and Egyptian roads.—4. Roads constructed by order of Semiramis.—5. Internal communication in ancient Greece.—6. Roads of the Phœnicians and Carthaginians.—7. Roman military roads.—8. Commercial intercourse during the middle ages.—9. Influences of the crusades on the art of transport.—10. Roads and intercommunication on the Continent to the middle of the seventeenth century.—11. System of roads projected by Napoleon.—12. Improvement in internal communication after the peace of 1815 —Roads of France —13. First roads in England, those made by the Romans.—14. Watling Street, Ermine Street, Fosse-way and Ikenald.—15. First attempts to improve roads in Great Britain in reign of Charles the Second.—16. Transport in Scotland to the middle of the eighteenth century.—17. Slowness of travelling in Scotland.—

PAGE

18. Arthur Young's account of the roads in England in 1770.—19. Comparison between cost and speed of former and present modes of transport.—20. Origin of railways in England.—21. Their immediate effects.—22. Progress of the construction.—23. Their extent in 1852.—24. Capital absorbed by them.—25. Labour employed by them . . . . . . 17

THE MOON.

1. Interest with which the moon is regarded, and influences with which it has been invested by the popular mind.—2. Its distance.—3. Its orbit.—4. Its magnitude.—5. Its rotation.—6. Conjunction.—7. Quadrature.—8. Opposition.—9-11. Tests of an atmosphere.—12-13. None exists on the moon.—14. No liquids.—15. No diffusion of solar light.—16. Appearance of earth seen from moon.—17. It would have belts.—18. Geographical features and its rotation would be visible through the clouds.—19. Moonlight neither warm nor cold.—20. Moon's physical condition.—21. Thickly covered with mountains.—22. Selenographical discoveries of Beer and Mädler.—23. Vast extent and diameter of the lunar mountains.—24. Circular chains.—25. Description of Tycho.—26. Heights of lunar mountains.—27. Observations of Lord Rosse.—28. Moon not inhabited. . . . . . 33

COMMON THINGS.—THE EARTH.

1. Difficulty of observing the earth as a whole.—2. It appears at first an indefinite flat surface.—3. This disproved by travelling round it.—4. Proof of the curvature of its surface by observation of distant objects at sea.—5. By the Earth's shadow projected on the Moon.—6. Inequalities of surface, such as mountains and valleys, insignificant. — 7. Magnitude of Earth, how ascertained. — 8. Length of a degree of latitude.—9-10. Illustrations of the Earth's magnitude.—11. Is the Earth at rest?—12. Apparent motion of the firmament.—13. Origin of the word "Universe."—14. This apparent motion may not be real—may arise from the rotation of the Earth.—15. How such a rotation would produce it.—16. Poles.—17. Equator.—18. Hemispheres.—19. Meridians.—20. Which of the two rotations is the more probable?—21. Rotation of the universe impossible.—22. Simplicity of the supposed rotation of the globe.—23. Direct proofs of this motion.—24. Foucault's experiment.—25. Its analogy to the planets.—26. Conclusion as to the globular form of the earth requires modification.—27. All human knowledge tentative and approximative.—28. Rotation not compatible with the exact globular form.—29. Centrifugal force of the Earth's rotation.—30. The globe rotating would assume the form of an oblate spheroid.—31. The degree of ellipticity would vary with the velocity of rotation.—32. Experimental illustration.—33. Ellipticity corresponding to the diurnal rotation.—34. How these circumstances affect the actual state of the Earth.—35. Form of a terrestrial

PAGE

meridian.—36. Dimensions of the terrestrial spheroid.—37. Its departure from an exact globe very small.—38. Its density and mass.—39. Determined by Cavendish and Maskelyne.—40. Its total weight. . . . . . . . . . 49

## TERRESTRIAL HEAT.

CHAP. I.—1. Heat an important agent.—2. Its local variations.—3. Diurnal period.—4. Annual period.—5. Mean diurnal temperature.—6. Mean monthly temperature.—7. Mean annual temperature.—8. Temperature of a place.—9. Isothermal lines.—10. Isothermal zones.—11. Thermal equator.—12. Second isothermal zone.—13. Third.—14. Fourth.—15. Fifth and Sixth.—16. Polar regions.—17. Climate varies on the same isothermal line.—18. Constant, variable, and extreme climates.—19. Classification of climates.—20. Extreme temperature in torrid and frigid zones.—21. Elevation affects temperature.—22. Snow line.—23. Thermal conditions below the surface.—24. Stratum of invariable temperature.—25. Varies with the latitude.—26. Its form.—27. Conditions above it.—28. Conditions below it.—29. Temperature of springs.—30. Temperature of greatest density of water.—31. Thermal condition of seas and lakes.—32. Thermal condition of a frozen sea.—33. Process of thawing.—34. Depth of stratum of constant temperature.—35. Superficial agitation extends only to a small depth.—36. Great utility of the state of maximum density.—37. Variations of temperature of the air.—38. Interchange of Equatorial and Polar waters.—39. Polar ice.—40. Ice-fields.—41. Icebergs.—42. Their forms and magnitude.—43. Sunken icebergs.—44. Curious effects of their superficial fusion.—45. Depth of Polar Seas.—46. Cold of Polar regions . . . . . . 65

CHAP. II.—47. Sources of external heat.—48. Solar heat.—49. Its quantity ascertained.—50. Heat at sun's surface.—51. Temperature of celestial spaces.—52. Quantity of heat supplied by them.—53. Summary of heat supplied.—54. Winds.—55. Produced by rarefaction and compression.—56. Sudden condensation of vapour.—57. Hurricanes.—58. Their cause.—59. Waterspouts.—60. Evaporation.—61. Saturation of air.—62. May arise from intermixing strata.—63. Effect of pressure.—64. Dew.—65. Hoar frost.—66. Artificial ice.—67. Fogs and clouds.—68. Rain.—69. Its quantity.—70. Snow.—71. Hail.—72. Hailstones.—73. Extraordinary hailstones . . . . 81

## THE SUN.

1. An object of great interest.—2. Its distance.—3. Magnitude.—4. Illustrations.—5. Its volume.—6. Mass or weight.—7. How ascertained.—8. Application of this principle.—9. Its density.—10. Form and rotation.—11. Determined by the appearance of spots.—12. Discovery of Solar spots.—13. Their

PAGE

great magnitude.—14. Their rapid changes.—15. Hypotheses to explain them.—16. They are excavations in the luminous coating.—17. Their prevalence varies.—18. Observations upon them.—19. Their dimensions.—20. Facules and Lucules.—21. Physical state of the Solar surface.—22. Luminous coating is gaseous.—23. Gaseous atmosphere outside it.—24. Effects of such an atmosphere on radiation.—25. Hypothesis of Sir J. Herschel. — 26. Intensity of heat at Sun's surface. — 27. Supposed source of heat . . . . . . . . . 97

## THE ELECTRIC TELEGRAPH.

CHAP. I.—1. Subjugation of the powers of nature to human uses.—2. Locomotion twenty years since.—3. Circulation of intelligence then.—4. Supposed prediction of succeeding improvements—Railway locomotion.—5. Electric telegraphy.—6. Fabrication of diamonds—sun-pictures—gas-lighting—electro-metallurgy. — 7. Such predictions would have been deemed incredible.—8. Electro-telegraphy the most incredible of all.—9. Remarkable experiment by Messrs. Leverrier and Lardner.—10. Velocity of electric current.—11. No limit to the celerity of telegraphy.—12. Physical character of electricity.—13. Not essential to the explanation of electro-telegraphy.—14. Electricity a subtle fluid.—15. Properties available for telegraphy.—16. Voltaic battery.—17. It is to the electric telegraph what the boiler is to the steam-engine.—18. Means of transmitting the fluid in required directions.—19. Conductors and insulators.—20. Conducting wires.—21. Voltaic battery.—22. Transmission and suspension of the current.—23. Current established by earth contact.—24. Theories of earth contact.—25. The return of the current through the earth.—26. Various bodies evolve electricity.—27. Common plate battery of zinc and copper.—28. Why zinc and copper are preferred.—29. Charcoal substituted for copper.—30. Elements not essential.—31. Various chemical solutions used.—32. Daniel's constant battery.—33. Same modified by Pouillet.—34. Grove's and Bunsen's batteries.—35. Necessary to combine many elements . . . . . . . . 113

CHAP. II.—36. Common plate battery. — 37. Combination of currents.—38. Loss of intensity by imperfect conduction.—39. Cylindrical batteries.—40. Pairs, elements, and poles defined.—41. Origin of term *voltaic pile*.—42. Use of sand in charging batteries.—43. To vary intensity of current.—44. Batteries used for English telegraphs.—45. Amalgamating the zinc plates.—46. The line-wires, material and thickness.—47. Objection to iron wires.—48. Manner of carrying wires on posts.—49. Good insulation.—50. Expedients for obtaining it.—51. Forms of insulating supports.—52. Dimensions and preparations of the posts.—53. Forms of support used in England.—54. Winding posts.—55. Supports in France.—56. In America.—57. In Germany.—58. Wire insulated by superficial oxydation.—59. Leakage of the electric fluid by the conduction of the atmosphere.

PAGE

—60. Effects of atmospheric electricity on the wires. — 61. Lightning conductors. — 62. Those of Messrs. Walker and Breguet.—63. Conducting current into stations.—64. Underground wires.—65. Methods of insulating them.—66. Testing posts . . . . . . . . . . . . 129

CHAP. III.—67. Wires of Magneto-electric Telegraph Company.—68. Mr. Bright's method of detecting faulty points.—69. Such failure of insulation rare.—70. Underground method recently abandoned in Prussia.—71. Underground wires of the European and Submarine Company.—72. Imperfect insulation in tunnels.—73. Mr. Walker's method of remedying this.—74. Overground system adopted through the streets of cities in France, and in the United States.—75. Telegraphic lines need not follow railways.—76. Do not in America.—77. Submarine cables.—78. Cable connecting Dover and Calais.—79. Failure of first attempt —Improved structure.—80. Table of submarine cables and their dimensions.—81. Dimensions and structure of the Dover and Calais cable.—82. Holyhead and Howth cable.—83. First attempt to lay cable between Portpatrick and Donaghadee—its failure.—84. Dover and Ostend.—85. Portpatrick and Donaghadee.—86. Orfordness and the Hague. . . . . . . 145

CHAP. IV. — 87. Cable between Spezzia and Corsica.—88. Other cables, European and American.—89. Objections brought by scientific authorities to the submarine cables.—Answers to these by practical men.—90. Example of a cable uninjured by the action of the sea.—91. Precautions necessary in laying the cable. —92. Accident in laying the Calais cable.—93. Imperfection attributed to the Belgian cable.—94. Transatlantic Ocean Telegraph.—95. Underground wires between the Strand and Lothbury.—96. Effect of the inductive action of underground or submarine wires.—97. Possible influence of this on telegraphic operations.—98. Examples of overground wires extended to great distances without intermediate support—between Turin and Genoa.—99. Telegraphic lines in India.—100. Difficulties arising from atmospheric electricity—height and distance of posts—mode of laying underground wires—extent of line erected to April 1854.—101. Intensity of current decreases as the length of wire increases.—102. Also increases with the thickness of the wire.—103. And with the number of elements in the battery.—104. Result of Pouillet's experiments on the intensity of current.—105. Intensity produced by increasing the power of the battery. —106. How the current produces telegraphic signals.—107. Velocity of the current.—108. Transmission of signals instantaneous . . . . . . . . . . . 161

CHAP. V.—109. Current controlled by making and breaking the contact of conductors.—110. Instruments for controlling the current.—Commutators.—111. General principle of the commutators.—112. Its application to telegraphic operations.—113. To transmit a current on the up-line only.—114. On the down-line only. —115. On both lines.—116. To reverse the current.—117. To suspend and transmit it alternately.—118. How to manage a

PAGE

current which arrives at a station.—119. To make it ring the alarum.—120. Station with two alarums.—121. Notice of the station transmitting and receiving signals.—122. When signals not addressed to the station the current is passed on.—123. How to receive a despatch at the station, and stop its farther progress. —124. How several despatches may be at the same time sent between various stations on the same line.—125. Secondary lines of wire then used.—126. Recapitulation.—127. Signals by combinations of unequal intervals of transmission and suspension.—128. Key commutator.—129. Horological commutator for a current having equal and regular pulsations.—130. Case in which the pulsations are not continuous or regular.—131. No limit to the celerity of the pulsations.—132. Application of a toothed wheel to produce the pulsations.—133. By a sinuous wheel.—134. Method of diverting the current by a short circuit, its application to the alarum.—135. Effects of the current which has been used for signals.—136. Deflection of magnetic needle. 177

CHAP. VI.—137. Relation of the deflection to the direction of the current.—138. Galvanometer or multiplier.—139. Method of covering the wire.—140. Method of mounting the needle.—141. Method of transmitting signals by the galvanometer.—142. How the current may produce a temporary magnet.—143. Electro-magnet constructed by Pouillet.—144. Electro-magnets formed by two straight bars.—145. They acquire and lose their magnetism instantaneously.—146. Magnetic pulsations as rapid as those of the current.—147. How they are rendered visible and counted.—148. Extraordinary celerity of the oscillations thus produced.—149. They produce musical sounds by which the rate of vibration may be estimated.—150. How the vibrations may impart motion to clock-work.—151. Their action on an escapement.—152. How the movement of one clock may be transmitted by the current to another.—153. How an electro-magnet may produce written characters on paper at a distant station.—154. How the motion of the hand upon a dial at one station can produce a like motion of a hand upon a dial at a distant station.—155. How an agent at one station can ring an alarum at another station.—156. Or may discharge a gun or cannon there.—157. Power of the bell or other signal not dependent on the force of the current.—158. Mechanism of telegraphic alarum.—159. Various alarums in telegraphic offices. —160. Magneto-electricity.—161. Method of producing a momentary magneto-electric current.—162. Application of an electro-magnet to produce it . . . . . . . 193

# LOCOMOTION AND TRANSPORT,

## THEIR INFLUENCE AND PROGRESS.

## CHAPTER I.

### INFLUENCE OF IMPROVED TRANSPORT ON CIVILISATION.

1. Art of transport essential to social advancement. — 2. Its rapid advancement in modern times.—3. Commerce mainly dependent on it. —4. Its conditions.—5. Its advantages, its influence on price.—6. Example of cotton. — 7. Agricultural products. — 8. Reciprocal advantages to rural and urban population.—9. Absence of good means of transport injurious to France.—10. Renders worthless or injurious articles serviceable and valuable.—11. Stimulates both production and consumption.—12. Increases the demand for labour. 13. Effects of railways.—14. Advantages of increased speed.—15. In the transport of cattle.—16. Steam vessels not so well adapted to this.—17. Supply of milk to towns.—18. Advantages to farmers and landlords.—19. Advantages of steam navigation.—20. Advantages of personal locomotion.—21. In the case of the working population. —22. Influence on the value of land.—23. Advantages to the population of large cities.—24. Relative speed of horse coaches and railways. 25. Military advantages.—26. Offers inducements to peace and the means of abridging war.—27. Influence on the diffusion of knowledge. —28. The electric telegraph.—29. Journalism.

1. The art by which the products of labour and thought, and the persons who labour and think, are transferred from place to place, is, more than any other, essential to social advancement. Without it no other art can progress. A people who do not possess it cannot be said to have emerged from barbarism. A people who have not made some advances in it, cannot yet have risen above a low state of civilisation. Nevertheless, this art has been, of all others, the latest in attaining a state of perfection, so late, indeed, that the future historian of social progress will record, without any real violation of truth, that its creation is one of the events which have most eminently signalised the present age and generation. For, although transport by land and water was practised by our forefathers, its condition was so immeasurably below that to which it has been carried in our times, that a more adequate idea of its actual state will be conveyed by calling it a new art, than by describing it as an improvement on the old one.

2. But if human invention has been late in directing its powers to this object, it must be admitted to have nobly compensated for the tardiness of its action by the incomparable rapidity of advancement it has produced, when once they have been brought into play. Within a hundred years, more has been accomplished in facilitating and expediting intercommunication, than was effected from the creation of the world to the middle of the last century. This statement may, perhaps, appear strained and exaggerated, but it will bear the test of examination.

3. The geographical conditions of the world, the distribution of the people who inhabit it, and the exclusive appropriation of its natural productions destined for their use to the various countries of which it consists, have imposed on mankind the necessity of intercommunication and commerce. Commerce is nothing more than the interchange of the productions of industry between people and people. Such interchange presupposes the existence of the art of transport by land and water. In proportion to the perfection of this art will be the extent of commerce.

A people incapable of communicating with others must subsist exclusively upon the productions of its own labour and its own soil. But nature has given us desires after the productions of other soils and other climates. Besides this, the productions of each particular soil or country are obtainable in superfluity. They are infinitely more in quantity than the people by whom and amidst whom they are produced have need of; while other and distant peoples are in a like situation, having a superfluity of some products and an insufficiency or a total absence of others. The people of South Carolina and Georgia have a superfluity of cotton, the people of the West India Islands have a superfluity of coffee and tobacco, the people of Louisiana have a superfluity of sugar, the people who inhabit the vast valley of the Upper Mississippi and Missouri have a superfluity of corn and cattle, the people of civilised Europe have a superfluity of the products of mechanical labour, those of France have a superfluity of silk goods, those of England of manufactured cotton, pottery, and hardware. Each of these various peoples is able and willing to supply the others with those productions in which themselves abound, and to receive in exchange those of which they stand in need, and which abound elsewhere.

4. But, to accomplish such interchanges, means of transport must be provided, and this transport must be sufficiently cheap, speedy, safe, and regular, to enable these several productions to reach their consumers, and be delivered on such terms and conditions as will be compatible with the ability to purchase them.

5. Among the advantages which attend improved means of transport, one of the most prominent is that of lowering the price of all commodities whatever in the market of consumption, and thereby stimulating production. The price paid for an article by its consumer consists of two elements: 1st, the price paid for the article to its producer at the place of its production; and, 2ndly, the expense of conveying it from that place to the consumer. In this latter element is included the cost of its transport and the commercial expenses connected with such transport. These last include a variety of items which enter largely into the price of the commodity, such as the cost of transport, properly so called, the interest on the price paid to the producer proportionate to the time which elapses before it reaches the consumer, the insurance against damage or loss during the transport. This insurance must be paid directly or indirectly by the consumer. If it be not effected by those who convey the commodity to the consumer, the value of the goods which may be lost or damaged in the transport will necessarily be charged in the price of those which arrive safe. In either case the consumer pays the insurance. There are also the charges for storage, packing, transhipment, and a variety of other commercial details, the total of which forms a large proportion of the ultimate price.

In many cases, these expenses incidental to transport amount to considerably more than half the real price of the article; in some they amount to three-fourths or four-fifths, or even a larger proportion.

6. Let us take the example of raw cotton produced on the plains of South Carolina or Georgia. This article is packed in bales at the place of production. These are then transported to Charleston or Savannah, whence they are exported to Liverpool. Arriving

at Liverpool, they are transferred upon the railway, by which they are transported to Manchester, Stockport, Preston, or some other seat of manufacture. The raw material is there taken by the manufacturer, spun into thread, woven into cloth, bleached and printed, glazed, and finished. It is then repacked, and again placed on the railway and transported once more to Liverpool, when it is re-embarked for Charleston or Savannah, for example. Arriving there, it is again placed on a railway or in a steam-boat, and is transported to the interior of the country, and finally returns to the very place at which it originally grew, and is repurchased by its own producer. Without going into arithmetical details, it will be abundantly apparent how large a proportion of the price thus paid for the manufactured article is to be placed to the account of the transport and commercial expenses. The article has made the circuit of almost half the globe before it has found its way back in its manufactured state.

7. The products of agricultural labour have, in general, great bulk with proportionately small value. The cost of transport has consequently a great influence upon the price of these in the market of consumption. Unless, therefore, this transport can be effected with considerable economy, these products must be consumed on the spot where they are produced.

In the case of many animal and vegetable productions of agriculture, speed of transport is as essential as cheapness, for they will deteriorate and be destroyed by the operation of time alone. Without great perfection, therefore, in the art of transport, objects of this class must necessarily be consumed in the immediate neighbourhood of the place where they are raised. Such are, for example, the products of the dairy, the farm-yard, and the garden.

8. In countries where transport is dear and slow, there consequently arises great disadvantage, not only to the rural, but also to the urban population. While the class of articles just referred to are at a ruinously low price in the rural districts, they are at a ruinously high price in the cities and larger class of towns. In the country, where they exist in superfluity, they fetch comparatively nothing: in the towns, where the supply is immeasurably below the demand, they can only be enjoyed by the affluent.

But if sufficiently cheap and rapid means of transport be provided, these productions find their way easily to the great centres of population in the towns, and the rural population which produces them receives in exchange innumerable articles of use and luxury of which they were before deprived.

9. France, one of the most civilised states of Europe, exhibits a deplorable illustration of this. Notwithstanding the fertility of

her soil, the number, the industry, and intelligence of her population, the products of every description, animal and vegetable, which abound in her territory, yet, from the absence of sufficiently easy means of intercommunication, these advantages have been hitherto almost annihilated. All these productions, in the place where they are raised, can be obtained at a lower price than in most other countries; and yet, in consequence of the cost of transport, they would attain, if brought to the place where they are in demand, a price which would amount to a prohibition on their consumption. From this cause the industry of France has long been to a great extent paralysed.

10. In some cases the price of an article at the place of consumption consists exclusively of the cost of transport. An article has frequently no value in the place where it is found, which nevertheless would have a considerable value transported elsewhere. Numerous instances of this will occur in the case of manures used in agriculture. Every reduction, therefore, which can be made in the cost of the transport of these, will tend in a still greater proportion to lower their price to those who use them.

Cases even occur in which the cost of transport is actually greater than the price paid for an article by the consumer. This, which would seem a paradox, is nevertheless easily explained. An article in a given place may be a nuisance, and its possessor may be willing to pay something for its removal. This article, however, transported to another place, may become eminently useful, and even be the means of stimulating profitable production. The cleansing the common sewers of a city affords a striking example of this. The filth and offal which are removed are a nuisance where they exist, and may even be the cause of pestilence and death. Transported, however, to the fields of the agriculturist, they become the instruments of increased fertility. Cases may be cited where the whole cost of transport will be more than covered by the sum paid for the removal of the nuisance.*

11. Every improvement in the art of transport having a tendency to diminish cost, and augment speed and safety, operates in a variety of ways to stimulate consumption and production, and thereby advance national wealth and prosperity. When the price of an article in the market of consumption is reduced by this cause, the demand for it is increased: 1st, by enabling former consumers to use it more freely and largely; and, 2ndly, by placing it within the reach of other classes of consumers who were before compelled to abstain from it by its dearness. The increase of

* In Aberdeen the streets were swept every day, at an annual cost of 1400*l*., and the refuse brought in 2000*l*. a-year. In Perth the scavenging cost 1300*l*. per annum, and the manure sold for 1730*l*.

consumption from this cause is generally in a larger ratio than the diminution of price. The number of consumers able and willing to pay one shilling for any proposed article is much more than twice the number who are able and willing to pay two shillings for the same article.

But consumption is also augmented in another way by this diminution of price. The saving effected by consumers who, before the reduction, purchased at the higher price, will now be appropriated to the purchase of other articles of use or enjoyment, and thus other branches of industry are stimulated.

12. The improvements which cheapen transport, necessarily including the expenditure of less labour in effecting it, might seem, at first view, to be attended with injury to the industry employed in the business of transport itself, by throwing out of occupation that portion of labour rendered superfluous by the improvement. But experience shows the result to be the reverse. The diminished cost of transport invariably augments the amount of commerce transacted, and in a much larger ratio than the reduction of cost; so that, in fact, although a less amount of labour is employed in the transport of a given amount of commodities than before, a much larger quantity of labour is necessary by reason of the vast increase of commodities transmitted. The history of the arts supplies innumerable examples of this. When railways were first brought into operation, it was declared, by the opponents of this great improvement (for it had opponents, and violent ones), that not only would an immense amount of human industry connected with the business of land carriage be utterly thrown out of employment, but also that a great quantity of horses would be rendered useless. Experience was not long in supplying a striking proof of the fallacy of this prevision.

13. The moment the first great line of railway was brought into operation between Liverpool and Manchester, the traffic between those places was quadrupled; and it is now well known that the quantity of labour, both human and chevaline, employed in land carriage where railways have been established, has been increased in a vast proportion, instead of being diminished.

In 1846 there were seventy-three stage-coaches or lines of omnibus employed in the transport of passengers to and from the several stations of the North of France Railway, which supplied 176 arrivals and departures, had 5776 places for passengers, and employed daily 979 horses. In the six months ending 31st December, 1846, these coaches transported 486948 passengers.

Improvements in transport which augment the speed, without injuriously increasing the expense or diminishing the safety, are attended with effects similar to those which follow from cheapness.

14. A part of the cost of transport consists of the interest on the cost of production chargeable for the time elapsed between the departure of the article from the producer and its delivery to the consumer. This element of price is clearly diminished in the exact proportion to the increased speed of transport.

But increased speed of transport also operates beneficially on commerce in another way. Numerous classes of articles of production become deteriorated by time, and many are absolutely destroyed, if not consumed within a certain time. It is evident that such articles admit of transport only when they can reach the consumer in a sufficiently sound state for use; various classes of articles of food come under this condition.

While the Houses of Parliament were occupied with the numerous railway acts which have been brought before them, a great mass of evidence was produced illustrating the advantages which both producer and consumer would obtain by the increased cheapness and expedition of transport which railways would supply. It was shown that the difficulties attending transport by common roads affected, in an injurious manner, the grazier who supplied the markets with veal and lamb. Lambs and calves were generally sent by the road; and when too young to leave the mothers for so long a time as the journey required, the producer was obliged to send the ewes or cows with them for at least a part of the way. This also rendered it impossible to send them to market sufficiently young, which it would have been advantageous to do, that the mothers might feed off earlier.

15. But, independently of this, the animals of every species driven to market on the common roads were proved to suffer so much from the fatigue of the journey, that when they arrived at market their flesh was not in a wholesome state. They were often driven till their feet were sore. Sheep frequently had their feet literally worn off, and were obliged to be sold on the road for what they would fetch. Extensive graziers declared that, in such cases, they would be gainers by a safe and expeditious transport for the animals, "even though it cost double the price paid to the drovers."

Butchers engaged in large business in London proved that the cattle driven to that market from considerable distances sustained so much injury that their value was considerably lessened, owing to the inferior quality of the meat, arising from the animal being slaughtered in a diseased state; that the animal being fatigued and overdriven "became feverish, his looks became not so good, and he lost weight by the length of the journey and the fatigue."

16. It was shown further, that even steam-vessels, when they could be resorted to, did not altogether remove this objection. Cattle arriving from Scotland in steam-vessels are found in London to be

in an unnatural state; "they seem stupified, and in a state suffering from fatigue."

It is not merely the fatigue of travelling which injures the animal, but also the absence from its accustomed pasture. The injury from this cause is more or less, under different circumstances, but always considerable: in order to obviate this, a large portion of the meat supplied to the London market was slaughtered in the country, and came in this state, in winter, from distances round London to the extent of one hundred miles. In warm weather a large quantity of it was spoiled. The transport of calves and lambs from a distance greater than thirty miles is altogether impracticable by common roads, and even from that distance is attended with difficulty and injury.

To convey these and other live cattle from a great distance, not only speed but evenness of motion is indispensable. Now these two requisites cannot be combined by any other means than the application of steam-engines upon a railroad.

The whole of the evidence showed that the supply of animal food to the metropolis was not only defective in quantity, but of unwholesome quality—comparatively, at least, with what it might be, if the tract from which it could be supplied were rendered more extensive.

**17.** But, forcibly as the evidence bore on this species of agricultural produce, it was still stronger respecting the produce of the dairy and the garden. Milk, cream, and fresh butter, vegetables of every denomination, and certain descriptions of fruit, were usually supplied exclusively from a narrow annulus of soil which circumscribes the skirts of great cities. Every artificial expedient was resorted to, in order to extort from this limited portion of land the necessary supplies for the population. The milk was of a quality so artificial, that we know not whether, in strict propriety of language, the name milk can be at all applied to it. The animals that yielded it were fed, not upon wholesome and natural pasturage, but, in a great degree, on grain and similar articles. It will not be supposed that the milk thus yielded is identical in wholesome and nutritious qualities with the article which could be supplied if a tract of land, of sufficient extent for the pasturage of cattle, was made subservient to the wants of such cities. Add to this that, inferior as must be under such circumstances the quality of the milk, there exist the strongest temptations to the seller who retails it to adulterate it still further before it finds its way to the table of the consumer.

Since the introduction of transport by railways, we see attached to the fast trains, morning and afternoon, numerous waggons loaded with tier over tier of milk-cans for the supply of the metropolitan population. Milk is thus brought from pastures at great distances from the cities where it is consumed. In Paris the benefits of this have been very conspicuous.

18. The benefits to farmers and landlords, as well as to the inhabitants of towns, by carrying extensive lines of railroad through populous districts, connecting them with those places from which supplies of food and other necessaries might be obtained, are always considerable. The factitious value which tracts of land immediately surrounding the metropolis and large towns acquire from the proximity of the markets, is thus modified, and a portion of their advantages transferred to the more remote districts; thus equalising the value of agricultural property, and rendering it, in a great measure, independent of local circumstances. The profit of the farmer and the rent of the landlord are augmented by the reduced cost of transport, while the price paid by the consumer is diminished; the advantages of centralisation are realised without incurring the inconvenience of crowding together masses of people within small spaces, and the whole face of the country is brought to the condition, and made to share the opportunities of improvement which are afforded by a metropolis and by towns of the larger class.

19. Steam navigation affords many striking examples of like advantages obtained in the transport of perishable productions.

Pines are now sold in the markets of England which are brought from the West Indies; various sorts of fruits are likewise brought from the countries on the coast of Europe which could not be transported in sailing vessels, as they would not keep during the voyage. Oranges are sent in large quantities from the Havannah to New Orleans and Mobile, in the United States: when they are brought by sailing vessels, a large proportion of the cargo is lost by the destruction and deterioration of the fruit; when sent by steamers, they arrive sound.

The utility of an article often depends on its place. Thus, what is useless at one part of the world will become eminently valuable if transmitted to another. We have already given examples of this in the case of agricultural manures. Others present themselves. Ice at mid-winter in Boston, Halifax, or St. John's, has no value; but this ice, properly packed and embarked, is transmitted to the Havannah or Calcutta, where a price is readily obtained for it which pays with profit the cost of the voyage.

Like all the other effects of improved transport, this reacts and produces collateral benefits. The ships thus enabled to go to Calcutta laden with a cargo which costs nothing and produces a considerable profit, instead of going in ballast, which would be attended with a certain expense, return with cargoes which again become profitable in the port from which they sailed, and which they could not have brought with profit unless aided by the expedient just mentioned.

20. Important as are improvements in the transport of the products of industry, they are less so than those which facilitate the transport of persons. Here speed becomes of paramount importance. In the case of the products of industry, the time of the transport is represented only by the interest on the cost of production of the article transmitted.

In the case of the transport of persons, the time of transport is represented by the value of the labour of the travellers, and their expenses on the road; and as travellers in general belong to the superior and more intelligent classes their time is proportionally valuable.

21. When cheapness can be sufficiently combined with speed, considerable advantage is gained by the operative classes.

The demand for labour in the several great centres of population varies from time to time, sometimes exceeding, and sometimes falling short of the supply. In the latter case, the operative having little other capital save his bodily strength, is reduced to extreme distress, nay, often even to mendicancy.

In the former case, the producer is compelled to pay an excessive rate of wages, which falls disadvantageously on the articles produced, in the shape of an undue increase of price, and thereby checks consumption. But although the equilibrium between supply and demand in the labour market is liable to be thus deranged, it rarely or never happens that it is subject to the same derangement in all the centres of population. Supply is never in excess everywhere at once, nor is it in all places at once deficient. Improvements in transport, which will render travelling cheap, easy, and expeditious, so as to bring it within the means of the thrifty and industrious operative, will enable labour to shift its place and seek those markets in which the demand is greatest. Thus, the places where the supply is in excess will be relieved, and those where the demand is in excess will be supplied.

22. The extent of soil by which great cities are supplied with perishable articles of food, is necessarily limited by the speed of transport. A ring of country immediately about a great capital, is occupied by market gardens and other establishments for supplying the vast population collected in the city with their commodities. The width of this ring will be determined by the speed with which the articles in question can be transported. It cannot exceed such a breadth as will enable the products raised at its extreme limit to reach the centre in such a time as may be compatible with their fitness for use.

It is evident that any improvement in transport which will double its speed will double the radius of this circle; an improvement which will treble its speed will increase the same radius in a threefold proportion. Now, as the actual area or quantity of soil included within such a radius is augmented, not in the simple ratio of the radius itself, but in the proportion of its square, it follows that a double speed will give a fourfold area of supply, a triple speed a ninefold area of supply, and so on. How great the advantages therefore are, which in this case attend increased speed, are abundantly apparent.

23. So far as relates to the transport of persons, the advantages of increased speed are equally remarkable. The population of a great capital is condensed into a small compass, and, so to speak, heaped together, by the difficulty and inconvenience of passing over long distances. Hence has arisen the densely populated state of great cities like London and Paris. With easy, cheap, and rapid means of locomotion, this tendency, so adverse to physical enjoyment and injurious to health, is proportionally neutralised. Distances practically diminish in the exact ratio of the speed of personal locomotion. And here the same arithmetical proportion is applicable. If the speed by which persons can be transported from place to place be doubled, the same population can, without inconvenience, be spread over four times the area; if the speed be tripled, it may occupy nine times the area, and so on.

Every one who is acquainted with the present habits of the population of London, and with those which prevailed before the establishment of railways, will perceive the practical truth of this observation. It is not now unusual for persons whose place of business is in the centre of the capital, to reside with their families at a distance of from fifteen to twenty miles from that centre. Nevertheless, they are able to arrive at their respective shops, counting-houses, or offices, at an early hour of the morning, and to return without inconvenience to their residence at the usual time in the evening. Hence in all directions round the metropolis in which railways are extended, habitations are multiplied, and a considerable part of the former population of London has been diffused in these quarters. The same will, of course, be applicable to the country which surrounds all other great towns. It is felt at Paris, Brussels, Berlin, Dresden, Vienna, and other capitals of Europe, just in the same proportion in which they are supplied with railway communication.

This principle of diffusion, however, is not confined to the towns only. It extends to an entire country when well intersected by lines of easy, rapid, and cheap communication.

The population, instead of being condensed into masses, is more uniformly diffused; and the extent of the diffusion which may be thus effected, compatibly with the same degree of intercourse, will be, to use an arithmetical phrase, in the direct proportion of the square of the speed of locomotion.

24. The common average of the speed of diligences in France and other parts of the Continent is two leagues, or about five miles, an hour. The speed of stage-coaches in England, before the establishment of railways, did not average eight miles an hour. According to the principle just explained, it would follow that the same degree of intercourse could be kept up in England in a space of sixty-four square miles, which in France could be maintained only within twenty-five square miles. Since the establishment of railways the average speed upon these lines of communication, on most parts of the Continent and in America, is fifteen miles an hour. By this improvement, so far as it has been carried, as compared with diligences, the area of practical communication, or, what is the same, of the diffusion of the population compatible with a given degree of intercourse, has been augmented in the ratio of the square of five to the square of fifteen; that is, in a ratio of twenty-five to two hundred and twenty-five. In other words, the same degree of intercourse can be maintained by means of the present railways within an area of two hundred and twenty-five square miles, as could be previously maintained by diligences within an area of twenty-five square miles.

But in England, where the average speed of railway transit is much greater, this power of diffusion is proportionally increased. Assuming the average speed on English railways at twenty-five miles an hour, which is less than its actual amount, the power of intercommunication thus obtained will bear to that obtained on the Continent of Europe where railways are in operation, the ratio of the square of twenty-five to the square of fifteen; that is, of six hundred and twenty-five to two hundred and twenty-five, or of twenty-five to nine.

Thus, the English railways afford the same facilities of communication within an area of twenty-five square miles as is afforded by the continental railways within an area of nine square miles; and thus, by augmenting the speed from fifteen to twenty-five miles an hour, the practical convenience to the public is augmented in the ratio of twenty-five to nine, or very nearly as three to one.

25. The importance of good internal communications in military affairs has long been acknowledged. By the possession of such means of transport as may enable a body of troops, with their arms and ammunition, to be transported promptly and rapidly from one part of the country to another, the standing army,

maintained as well for the purposes of order at home as for the defence of the frontiers, may be diminished in proportion to such facilities.

Instead of maintaining garrisons and posts at points of the country within short distances of each other, it will be sufficient to maintain them at such points that they can, at need, be transported with promptitude to any other point that may be desired. In case of invasion, or any foreign attack on the frontier, by good internal communications, the troops quartered throughout the interior can be rapidly transferred and concentrated upon the point attacked.

If, however, such improvements in the art of transport facilitate the means of maintaining order at home and of defence against a foreign enemy, on the one hand, they also happily, on the other, greatly diminish the probability of a necessity for such expedients. "The natural effect of commerce," says Montesquieu, "is to tend to and consolidate peace." Two nations who trade with each other soon become respectively dependent. If one have an interest to buy, the other has an interest to sell, and a multitude of ties, commercial and social, spring out of their mutual wants.

26. Nothing facilitates and developes commercial relations so effectually as cheap and rapid means of intercommunication. When, therefore, all nations shall be found more intimately connected with each other by these means, they will inevitably multiply their exchanges, and general commerce will undergo great extension, mutual interest will awaken moral sympathies, and will lead to political alliances. After having for ages approached each other only for war, peoples will henceforth visit each other for purposes of amity and intelligence, and old antipathies, national and political, which have so long divided and ruined neighbouring states, will speedily vanish.

But if, in spite of this general tendency towards pacific progress and peace, war should occasionally break out, the improved means of intercommunication will aid in bringing it to a prompt close. A single battle will decide the fate of a country, and the longest war will be probably circumscribed within a few months.

27. The advantages of good means of communication in the diffusion of knowledge, and the increase of civilisation by intellectual means, are not less considerable. While the means of intercommunication are slow, difficult, and costly, great cities have a tendency to monopolise intelligence, civilisation, and refinement. There genius and talent are naturally attracted, while the rural districts are left in a comparatively rude and almost barbarous state. With easy and rapid means of locomotion, however, the

best part of the urban population circulates freely through the country. This interfusion improves and civilises the rural population. The highest intelligence will be occasionally found, both in public and in private, diffusing knowledge and science in the remotest villages. We cannot now take up a London journal without observing announcements of men distinguished in the various branches of knowledge and art, visiting the various towns and villages of the provinces, and delivering their lectures on science, and entertainments and exhibitions in the fine arts. So rapid are the communications, that it is frequently announced that this or that professor or artist will, on Monday evening, deliver a lecture or entertainment in Liverpool, on Tuesday in Manchester, on Wednesday in Preston, on Thursday in Halifax, on Friday in Leeds, and so forth.

28. Nor is this all. The aspirations of the present generation after the spread of knowledge and the advancement of mind, unsatisfied with a celerity of transmission so rapid by the railway, which literally has the speed of the wind, has provoked from human invention still greater wonders. The Electric Telegraph for the transmission of intelligence, in the most literal sense of the term, annihilates both space and time. The interval which elapses between the transmission of a message from London and its delivery at Paris, Brussels, or Berlin, provided the line is uninterrupted, is absolutely inappreciable.

This system is now spreading throughout the whole civilised world. The United States of America are overspread with a network of electricity. The President's message delivered at Washington, was transmitted from thence to St. Louis, on the confines of the state of Missouri, a distance of about 1200 miles, in an hour. The news from Europe arriving at Boston by the Cunard steamers, is often transmitted to New Orleans, over almost the entire territory of the United States from north to south, a distance of nearly 2000 miles, in less time than would be necessary to commit it to paper. Even the small delay that now exists arises, not from any imperfection in the instrument of transmission, but merely from the line of electric communication being interrupted from point to point, and transferred from one system of telegraphs to another, at several intermediate stations. After improvements shall remove such delays as these, we shall probably see intelligence conveyed in an instant over a quadrant of the globe.

29. But if we would seek for a striking illustration of the effects of the rapid transmission of intelligence by the combination of all the various expedients supplied by science to art, it is in the practice of Journalism that we are to look for them, and more especially in

the great enterprises of the London newspapers. The proprietors of a single morning journal are able to maintain agencies, for the transmission of intelligence to the central office in London, in all the principal cities of Europe, besides roving correspondents wherever the prevalence of war, revolution, or any other public event excites a local interest. These various agents or "correspondents" as they are called, not only transmit to the centre of intelligence in London regular despatches by the mails, but also, on occasion of emergency, by special couriers.

These despatches are first received by an agent at Dover, by whom they are forwarded to London by a special messenger. But in cases where intelligence arrives of adequate importance, it is transmitted from the principal continental cities direct to London, in an abridged form, by the electric telegraph, thus anticipating the detailed despatches by many days. Within two hours of its arrival the intelligence is in the hands of the London public.

That portion of the journal intended for the provinces is sent to press at 3 A.M.; and by the activity of the editors, reporters, and compositors, all of whom work during the night, it includes not only the detailed reports of the Houses of Parliament, which often sit to a late hour in the morning, but also the foreign news, as above explained, by electric telegraph. This earliest impression is printed and delivered to the newsvenders, in sufficient time to be despatched to the provinces by the early railway trains, and it is thus delivered at all the stations along the road.

The part of the impression intended for London circulation is worked off and delivered later.

Thus we see that, by these combinations of enterprise, intellectual and material, the intelligence which arrives in London at 3 A.M., is written, composed, printed, and distributed within a radius of one hundred miles round London, and in the hands of the population before their customary hour of breakfast.

Even before the present improved methods of transport were brought into operation, wonders in this way were effected.

Thus, in some cases where debates of adequate public interest took place in Parliament in the evening, the evening mails (for there were then no other) carried to the provinces the first part of an important speech, reported and printed before the remaining part was spoken. Thus it was related that the commencement of Mr. (since Lord) Brougham's celebrated speech on the reform of the laws was read at tea-tables twenty miles from London before he had pronounced the peroration.

Few of the numerous readers of newspapers have the least idea of the immense commercial, social, and intellectual powers wielded, and benefits conferred, by these daily publications, a large portion of which influence is to be ascribed to the cheapness, promptitude, and rapidity with which they are transmitted from the capital to all parts of the country.

It is well known that the average number of copies of the most widely circulating London journal, which are daily issued, amounts at present to more than forty thousand. Each of these forty thousand copies, according to common estimation, passes under the eyes, upon an average, of at least ten persons. Thus we have four hundred thousand daily readers of one organ of information and intelligence. But the effects do not end there. These four hundred thousand *readers*, long before the globe completes a revolution on its axis, become four hundred thousand *talkers*, and have vastly more than four hundred thousand *hearers*. Thus they spread more widely by the ear the information, the arguments, and the opinions they have received through the eye. We shall certainly not be overstating the result if we assume, that this influence of a single journal, directly and indirectly, reaches daily a million of persons.


# LOCOMOTION AND TRANSPORT,

## THEIR INFLUENCE AND PROGRESS.

## CHAPTER II.

RETROSPECT OF THE PROGRESS OF TRANSPORT.

1. Of the first construction and improvement of roads and carriages.—2. Roads do not exist in more than two-sevenths of the inhabited parts of the globe.—3. Roman and Egyptian roads.—4. Roads constructed by order of Semiramis.—5. Internal communication in ancient Greece.—6. Roads of the Phœnicians and Carthaginians.—7. Roman military roads.—8. Commercial intercourse during the middle ages.—9. Influences of the crusades on the art of transport.—10. Roads and intercommunication on the Continent to the middle of the seventeenth century.—11. System of roads projected by Napoleon.—12. Improvement in internal communication after the peace of 1815. roads of France.—13. First roads in England, those made by the Romans.—14. Watling Street, Ermine Street, Fosse-way and Ikenald.—15. First attempts to improve roads in Great Britain in reign of Charles the Second.—16. Transport in Scotland to the middle of the eighteenth century.—17. Slowness of travelling in Scotland.—18. Arthur Young's account of the roads in England in 1770.—19. Comparison between cost and speed of former and present modes of transport.—20. Origin of railways in England.—21. Their immediate effects.—22. Progress of the construction.—23. Their extent in 1852.—24. Capital absorbed by them.—25. Labour employed by them.

1. In the first attempts at an interchange of the products of industry, which mark the incipient commerce of a people emerging from barbarism, human labour and the strength of the inferior animals, applied in the most rude and direct manner to transport, are all the means brought into play. The pedlar and the pack-horse perform all the operations of interchange which take place in an infant society. Pathways are formed over the natural surface of the ground, in a course more or less direct, between village and village. The beds of streams following, by the laws of physics, the lowest levels, serve as the first indication to the traveller how to avoid steep acclivities, and, by deviating from the most direct and shortest course, to obtain his object with a diminished amount of labour.

As industry is stimulated and becomes more productive, invention is brought more largely into play, and these rude expedients are improved. Wheel carriages are invented, but the earliest theatre of their operations is the immediate surface of the soil from which the products of agriculture are raised. They are used to gather and transport these to a place where they may be sheltered and secured.

But to enable wheel carriages to serve as the means of transport between places more or less distant, the former horse-paths are insufficient. A more uniform and level surface, and a harder substratum, become indispensable. In a word, a Road, constructed with more or less perfection, is necessary.

These roads, at first extremely rude and inartificial, and rendered barely smooth and hard enough for the little commerce of an infant people, are gradually improved. The carriages, also, which serve as the means of transport undergo like improvement, until, after a series of ages, that astonishing instrument of commerce, the modern road, results, which is carried on an artificial causeway, and reduced, at an enormous expense, to a nearly level surface by means of vast excavations, extensive embankments, bridges, viaducts, tunnels, and other expedients supplied by the skill and ingenuity of the engineer.

Between the pack-horse, used in the first stages of growing commerce, and such a road with its artificial carriages, there is a prodigious distance. The first step, from the pack-horse to the common two-wheel cart, was, in itself, a great advance.

It is calculated that a horse of average force, working for eight or ten hours a day, cannot transport on his back more than two hundredweight, and that he can carry this at the rate of only twenty-five miles a day over an average level country. The same horse, working in a two-wheel cart, will carry through the same distance per day twenty hundredweight, exclusive of the weight of the cart. By this simple expedient, therefore, the art of transport was improved in the ratio of one to ten; in other words, the transport which before was effected at the cost of ten pounds, was, with this expedient, reduced to the cost of one pound.

2. The adoption of expedients for the maintenance of commerce so obvious as roads, would seem to be inevitable among a people who are not actually in a state of barbarism. Nevertheless, we find that not only was the construction of good roads for commercial purposes of comparatively recent date, but that, even at the present day, a very large portion of that part of the world called civilised, is unprovided with them. With the exception of certain parts of Europe, the French colony of Algeria, and the United States, the entire surface of the world is still without this means of intercourse.

It is calculated that, of the entire inhabited part of the globe, roads do not exist in more than *two-sevenths*. The extensive empire of Russia, with the exception of one or two main communications, such as that between Petersburg and Moscow, is without them. In general, the only practicable communications through this vast territory are effected in winter on the surface of the frozen snow by sledges. On the return of summer, when the snow has disappeared, the communications become extremely difficult, slow, and expensive. Spain is scarcely better supplied with roads than Russia, nor do we find much improvement in the practice of transport in Italy. Until recently, Corsica possessed no communications of this sort; horses and mules were the common means of communication and interchange in that island until the French government constructed some roads.

3. The roads constructed by the Romans and Egyptians will probably be referred to as instances of an early advance in this art. But these great monuments of antiquity, though serving incidentally, to some extent, as means of commerce, were constructed for exclusively military purposes.

4. The most ancient roads which are recorded in history, are those constructed by order of Semiramis, throughout the extent of her empire. It would seem, however, that the commerce of that day did not find these communications suitable to its objects; for it is certain that, at the epoch at which Tyre and Carthage were signalised for their enterprise, their commerce was almost exclusively carried on by the coasting navigation of the Mediterranean.

5. Notwithstanding the advanced stage to which civilisation had arrived in Greece, the means of internal communication in that country remained in a state of great imperfection. This may in

part be explained by the multitude of small states which formed that confederation, by their conflicting interests, and their want of any moral or social sympathies. The common sentiment of nationality slumbered, except when it was awakened by the strong stimulus of foreign attack. The intercourse between one centre of population and another was then very restrained, and although the public ways were placed under the protection of the gods, and the direction of the most considerable men of the respective states, they were suffered to fall into neglect. The exigencies of internal commerce were never sufficiently pressing to excite the people to contribute to the maintenance of good means of intercommunication and exchange.

6. The earliest roads which were really rendered conducive to the purposes of commerce, on any considerable scale, were those constructed by the Phenicians and Carthaginians. To the latter is ascribed, by Isidore, the invention of paved roads.

7. When imperial Rome attained the meridian of her power, and her empire extended over a large portion of Europe and Asia, colossal enterprises were entered upon for the construction of vast lines of communication, extending over the immensity of her territory. These roads, however, like those of the Egyptians, were constructed without the slightest view to commercial objects. It concerned imperial Rome but little, that her provinces should be united by commercial or social interests. What she looked to was to be enabled to convey with celerity her powerful legions at all times from one extremity of her dominions to another. With this purpose, she availed herself of her vast resources to construct those military roads, intersecting her territory, the remains of which have excited the admiration of succeeding generations.

The first of these great monuments of the enterprise and art of the Roman people were those so well known by the names of the Via Appia, the Via Aurelia, and the Via Flaminia. Under Julius Caesar, communications were made by paved roads between the capital of the empire and all the chief towns. During the last African war, a paved road was constructed from Spain, through Gaul, to the Alps. Subsequently similar lines of communication were carried through Savoy, Dauphiné, Provence, through Germany, through a part of Spain, through Gaul, and even to Constantinople.

Asia Minor, Hungary, and Macedonia were overspread with similar lines of communication, which were carried to the mouths of the Danube. Nor was this vast enterprise obstructed by the intervention of seas. The great lines which terminated on the shores of continental Europe were continued at the nearest points of the neighbouring islands and continents. Thus, Sicily, Corsica, Sardinia, and England, and even Africa and Asia, were intersected and penetrated by roads, forming the continuation of the great European system.

These colossal works were not paths rudely prepared for the action of the feet of horses and the wheels of carriages, by merely removing the natural asperities from the surface of the soil. They were constructed, on the contrary, on principles in some respects as sound and scientific as those which modern engineering has supplied. Where the exigencies of the country required it, forests were felled, mountains excavated, hills levelled, valleys filled up, chasms and rivers bestridden by bridges, and marshes drained, to an extent which would suffer little by comparison with the operations of our great road-makers of modern times.

On the fall of the Empire, these means of communication, instead of subserving the purposes of the commerce of the people through whose territory they were carried, were, for the most part, destroyed. When the barbarians conquered Rome, and a multitude of states were formed from its ruins, the victors shut themselves up and fortified themselves in these several states, as an army does in a citadel; and, far from constructing new roads, they destroyed those which had already existed, as a town threatened with siege breaks those communications by which the enemy may approach it.

8. From this epoch through a long series of ages, the nations of Europe, animated only by a spirit of reciprocal antagonism, thought of nothing but war, and entered each other's territories only for the purposes of conflict. The history of the intercommunications of nations during the middle ages is only a history of their wars.

When Europe emerged from this state, and when commerce began to force itself into life, its operations were in a great measure monopolised by Jewish and Lombard merchants, who carried them on subject to the greatest difficulty and danger.

The provincial nobles and lords of the soil, through whose possessions the merchant necessarily passed in carrying on the internal commerce of the country, were nothing better than highway robbers. They issued with their bands from their castles and arrested the travelling merchant, stripping him of the goods which he carried for sale.

The sovereigns of France endeavoured in vain, by penal enactments, to check this enormous evil. Dagobert I. established a sort of code to regulate the public communications through his dominions, and decreed heavy fines against such provincial lords as might obstruct the freedom of communication, by interrupting or plundering travellers. These decrees, however, remained a dead letter, no adequate power in the state being able to carry them into practical effect.

Under the successors of Charlemagne, this abuse, which it was found impossible to repress, was, in some measure, recognised and regularised. Tolls of limited amount were allowed to be exacted by the local proprietors from those who passed through the provinces for purposes of trade, on the condition that such travellers or merchants should be otherwise unmolested.

The prevalence of all these vexatious impediments soon rendered intercommunication by land almost impracticable. The roads, such as they were, became accordingly deserted, and were suffered to fall into utter disrepair. During a series of ages, internal communication and internal commerce became almost suspended; a journey even of a few leagues being regarded as a most serious and dangerous undertaking.

9. The Crusades had a favourable influence on the art of transport. The population of Western and Northern Europe became by them acquainted with the productions and arts of the East. New desires were excited and new wants created. Commerce was thus stimulated, and greater facility of intercourse becoming necessary, governments were forced to adopt expedients for the security of the traveller.

The same difficulties and dangers did not, however, affect navigation. We find this art developed in a much higher degree than that of internal commerce. Hence arose the disproportionate commercial opulence of maritime people. The British, the Dutch, and the Portuguese rose into immense commercial importance, as well as the Genoese, the Tuscans, and the Venetians.

10. Even so late as the middle of the seventeenth century, the roads throughout the Continent continued in a condition which rendered travelling almost impracticable.

They are described by writers of this epoch as being absolute sloughs. Madame de Sevigny, writing in 1672, says, that a journey from Paris to Marseilles, which by the common roads of the present day is effected in less than sixty hours, required a whole month.

Besides the material obstacles opposed to the growth of internal commerce on the Continent by the want of roads in sufficient number, and the miserable state of those which did exist, other impediments were created and difficulties interposed by innumerable fiscal exactions, to which the trader was exposed, not only in passing the confines of different states, but even in going from province to province in the same state, and in passing through almost every town and village. Hence the cost of every commodity was enormously enhanced, even at short distances from the place of its production.

11. The disorganisation of society and the destruction of the institutions of feudalism which followed the French Revolution of 1789, caused some improvement in the means of internal commerce in Europe, and would have caused a much greater development in this instrument of civilisation, but for the wars which immediately succeeded that political catastrophe, and which only terminated with the battle of Waterloo.

Indeed Napoleon, conscious of the vast importance of a more complete system of roads, had actually projected one, which he intended to spread over Europe. His fall, however, intercepted the realisation of this magnificent design, and the *Simplon* remains as the only monument of his glory in this department of art.

After the re-establishment of peace, the nations of Europe, directing their activity to industry and commerce, soon became impressed with the necessity of effecting a great improvement in the means of internal communication. Western Europe, accordingly, soon began to be covered with roads and canals. The obstructions arising from fiscal causes, if not removed, were greatly diminished.

The advance made by France especially in this department, is deserving of notice. That country possesses at present four or five times the extent of roads which were practicable under the Empire; a sum of nearly four millions sterling was, until lately, expended annually upon the completion and maintenance of these great lines of communication.

The roads of France consist of three classes; the first, until the late revolution, were called *royal roads*, and are now called *national roads*. These are the great arteries of communication carried from one chief town to another throughout the territory, and being used indifferently, or nearly so, by the whole population, are constructed and maintained at the general expense of the nation. The second class are *departmental roads*, or what would be called in England *county roads*. These are chiefly the branches running into the royal roads, by which the local interests of the departments are served, and are accordingly maintained at the expense of the departments. Finally, the third class is called *vicinal roads*, which would correspond to our *parish roads*.

The rate at which these improved communications have contributed to augment the internal commerce and national wealth, may be estimated in some degree from the statistical results which have been published. In 1810, the various stage-coach establishments in Paris transported each day from the capital into the departments, two hundred and twenty passengers, and twenty-one tons of merchandise. Before the establishment of railways, they transported nearly one thousand passengers and forty-five tons of merchandise. Thus the passengers were augmented in a fourfold, and the merchandise in a twofold proportion.

12. In 1815, the length of roads in operation in France was as follows: there were three thousand leagues of royal roads, and two thousand leagues of departmental roads. In 1829, there were four thousand two hundred and five leagues of royal roads, and three thousand leagues of departmental roads. In 1844, there were eight thousand six hundred and twenty-eight leagues of royal roads, and nine thousand one hundred and forty-six leagues of departmental roads, independently of twelve thousand leagues of vicinal roads. Thus, it appears that between 1815 and 1844, the total length of roads of the first and second classes was augmented from five thousand leagues to nearly eighteen thousand, or in the proportion of three and a half to one.

13. Although the practice of road-making in England attained a certain degree of perfection at a much earlier period than in other parts of Europe, and the United Kingdom was overspread with a noble network of internal communications, while continental Europe remained in a comparatively barbarous condition, the art of transport nevertheless, even in England, remained for a long series of ages incalculably behind what would seem to be the commercial wants of the population.

The first English roads of artificial construction were those made by the Romans, while England was a province of that empire. The island was then intersected by two grand trunk roads running at right angles to each other, the one from north to south, and the other from east to west.

These main lines were supplied with various branches, extending in every direction which the conquerors found it expedient to render accessible to their armies.

14. The Roman road called *Watling Street* commenced from Richborough, in Kent, the ancient Rutupial, and, passing through London, was carried in a north-westerly direction to Chester. The road called *Ermine Street* commenced from London, and, passing through Lincoln, was carried thence through Carlisle into Scotland. The road called the *Fosse-way* passed through Bath in a direction N.E., and terminated in the Ermine Street. The road called *Ikenald* extended from Norwich in a southern direction to Dorsetshire.

But these great works, at the date of their construction, exceeded the wants of the population, who, unconscious of their advantage, allowed them to fall into neglect and disrepair. Nor were any new roads in other or better directions constructed. For a succession of ages the little intercourse that was maintained between the various parts of Great Britain was effected almost exclusively by rude footpaths, traversed by pedestrians, or at best by horses.

These were carried over the natural surface of the ground, generally in straight directions, from one place to another. Hills were surmounted, valleys crossed, and rivers forded by these rude agents of transport, in the same manner as the savages and settlers of the backwoods of America or the slopes of the Rocky Mountains now communicate with each other.

15. The first important attempt made to improve the communications of Great Britain took place in the reign of Charles II. In the sixteenth year of the reign of that monarch was established the first turnpike road where toll was taken, which intersected the counties of Hertford, Cambridge, and Huntingdon. It long remained, however, an isolated line of communication; and it was little more than a century ago that any extensive or effectual attempts were made, of a general character, to construct a good system of roads through the country.

16. Until the middle of the eighteenth century, most of the merchandise which was conveyed from place to place in Scotland was transported on pack-horses. Oatmeal, coals, turf, and even hay and straw, were carried in this manner through short distances; but when it was necessary to carry merchandise between distant places, a cart was used, a horse not being able to transport on his back a sufficient quantity of goods to pay the cost of the journey.

17. The time required by the common carriers to complete their journey seems, when compared with our present standard of speed, quite incredible. Thus, it is recorded that the carrier between Selkirk and Edinburgh, a distance of thirty-eight miles, required a fortnight for his journey, going and returning. The road lay chiefly along the bottom of the district called *Gala-water*, the bed of the stream, when not flooded, being the ground chosen as the most level and easy to travel on.

In 1678, a contract was made to establish a coach for passengers between Edinburgh and Glasgow, a distance of forty-four miles. This coach was drawn by six horses, and the journey between the two places, to and fro, was completed in six days. Even so recently as the year 1750, the stage-coach from Edinburgh to Glasgow took thirty-six hours to make the journey. In 1849, the same journey was made, by a route three miles longer, in one hour and a half!

In the year 1763 there was but one stage-coach between Edinburgh and London. This started once a month from each of these cities. It took a fortnight to perform the journey. At the same epoch the journey between London and York required four days.

In 1835 there were seven coaches started daily between London and Edinburgh, which performed the journey in less than forty-eight hours. In 1849, the same journey was performed by railway in twelve hours!

In 1763, the number of passengers conveyed by the coaches between London and Edinburgh could not have exceeded about twenty-five *monthly*, and by all means of conveyance whatever did not exceed fifty. In 1835 the coaches alone conveyed between these two capitals about one hundred and forty passengers *daily*, or four thousand monthly. But besides these, several steam-ships, of enormous magnitude, sailed weekly between the two places, supplying all the accommodation and luxury of floating hotels, and completing the voyage at the same rate as the coaches, in less than forty-eight hours.

As these steam-ships conveyed at least as many passengers as the coaches, we may estimate the actual number of passengers transported between the two places monthly at eight thousand. Thus the intercourse between London and Edinburgh in 1835 was one hundred and sixty times greater than in 1763.

At present the intercourse is increased in a much higher ratio, by the improved facility and greater cheapness of railway transport.

18. Arthur Young, who travelled in Lancashire about the year 1770, has left us in his Tour the following account of the state of the roads at that time. "I know not," he says, "in the whole range of language, terms sufficiently expressive to describe this infernal road. Let me most seriously caution all travellers who may accidentally propose to travel 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 after a winter? The only mending it receives is tumbling in some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions, but facts; for I actually passed three carts broken down in these eighteen miles of execrable memory."

And again he says (speaking of a turnpike road near Warrington, now superseded by the Grand Junction Railway,) "This is a paved road, most infamously bad. Any person would imagine the people of the country had made it with a view to immediate destruction! for the breadth is only sufficient for one carriage; consequently it is cut at once into ruts; and you may easily conceive what a break-down, dislocating road, ruts cut through a pavement must be."

Nor was the state of the roads in other parts of the north of England better. He says of a road near Newcastle, now superseded by a railway, "A more dreadful road cannot be imagined. I was obliged to hire two men at one place to support my chaise from overturning. Let me persuade all travellers to avoid this terrible country, which must either dislocate their bones with broken pavements, or bury them in muddy sand. It is only bad management that can occasion such very miserable roads in a country so abounding with towns, trade, and manufactures."

Now, it so happens that the precise ground over which Mr. Young travelled in this manner less than eighty years ago is at present literally reticulated with railways, upon which tens of thousands of passengers are daily transported, at a speed varying from thirty to fifty miles an hour, in carriages affording no more inconvenience or discomfort than Mr. Young suffered in 1770, when reposing in his drawing-room in his arm-chair.

19. Until the close of the last century, the internal transport of goods in England was performed by waggon, and was not only intolerably slow, but so expensive as to exclude every object except manufactured articles, and such as, being of light weight and small bulk in proportion to their value, would allow of a high rate of transport. Thus the charge for carriage by waggon from London to Leeds was at the rate of 13*l.* a ton, being 13½*d.* per ton per mile. Between Liverpool and Manchester it was forty shillings a ton, or 15*d.* per ton per mile. Heavy articles, such as coals and other materials, could only be available for commerce where their position favoured transport by sea, and, consequently, many of the richest districts of the kingdom remained unproductive, awaiting the tardy advancement of the art of transport. Coals are now carried upon railways at a penny per ton per mile, and, in some places, at even a lower rate. Merchandise, such as that mentioned above, which was transported in 1763 at from 14*d.* to 15*d.* per mile, is now carried at from 3*d.* to 4*d.*, while those sorts which are heavier in proportion to their bulk are transported at 2½*d.* per ton per mile.

But this is not all: the waggon transport formerly practised was limited to a speed which in its most improved state did not exceed twenty-four miles a day, while the present transport by railway is effected at the rate of from twelve to fourteen miles an hour.

20. When we look back upon the state in which every part of the civilised world was placed in relation to this vital element of social and commercial progress, this standard and test, as it may be justly called, of civilisation at an epoch so recent as the first year of the present century, and compare it with the present condition not of England only, but of Europe and North America, we cannot fail to be struck with the incalculable amount of benefit to the human race that must result from the extraordinary energy with which the discoveries and resources of science have been applied to the improvement of this instrument of civilisation within the brief interval of twenty-four years, for it is not more since the date of the commencement of railway transport in this country which took the lead in that, as in so many other improvements in the arts of life.

21. In 1830, the first railway for general traffic in passengers and goods between Liverpool and Manchester was opened; and immediately, of the thirty stage-coaches which had previously run daily between Liverpool and Manchester, one only remained on the road; and that was supported solely by passengers to intermediate places not lying in the direction of the railway.

The comparatively low fares and extraordinary expedition offered by the railway had the effect which might have been expected. Previously, the number of travellers daily, by the coaches, was about five hundred; it was immediately augmented above three-fold. Sixteen hundred passengers per day passed between these towns. If the traffic in passengers exceeded all anticipation, the transport of goods, on the contrary, fell short of what was expected. The canal lowered its tariff to the level of the railway charges and increased its speed and its attention to the accommodation of customers. The canal, moreover, winding through Manchester, washed the walls of the warehouses of the merchants and manufacturers. At the other end it communicated directly with the Liverpool docks. The goods were therefore received directly from the ship, and delivered directly to the warehouse, or *vice versâ;* without the cost, delay, and inconvenience of intermediate transhipment and cartage. These considerations went far to counterbalance the superior speed of the railway transit for goods; yet, notwithstanding this inconvenience and obstruction, the company soon found themselves carriers of merchandise at the rate of a thousand tons per day.

Thus, the problem of the rapid transport of passengers by steam on railways was solved in 1830, and the profitable character of the enterprise soon became apparent. Dividends of 10 per cent. were declared, and the shares were greedily bought up at 120 per cent. premium. Then followed in rapid succession those results which must necessarily have ensued. Other lines of railway, connecting the chief centres of population and industry with the metropolis, and with each other, were projected. In the four years which elapsed from 1832 to 1836, about 450 miles of railway were completed, and 350 miles were in progress of construction.

22. From 1836 to the present time the construction of these great lines of intercommunication in the United Kingdom has proceeded at a rate of progress of which no previous example has ever been recorded in the history of the industrial arts in any country. From the official reports presented to Parliament, it appears that the whole extent of railway communication open for traffic in the United Kingdom at the end of 1852 was 7336 miles, which were distributed in the different portions of the kingdom in the following proportions:—

| | |
|---|---|
| In England and Wales . . . . | 5650 miles. |
| In Scotland . . . . . . . | 978 |
| In Ireland . . . . . . | 708 |
| Total in the United Kingdom . . | 7336 miles open for public traffic. |

It further appears from these reports that, at the close of 1852, the legislature had authorised the construction of a total length of railway (including the above 7336 miles) amounting to 12561 miles, of which 676 miles had been abandoned by the companies which had originally undertaken them. Thus the account of the total amount authorised by Parliament, to the end of 1852, stood thus:—

| | |
|---|---|
| Constructed and in operation. . . | 7336 miles. |
| In progress or intended to be commenced | 4549 |
| Abandoned . . . . . . | 676 |
| | 12561 miles. |

23. The following table, taken from the report of the Committee of the Privy Council, dated August, 1853, will exhibit the rate at which the railway projects were sanctioned by Parliament, and the rate at which their execution has progressed up to the end of 1852:—

TABLE showing the Proportion of Railways authorised previous to the end of 1843, and in each succeeding Year, opened for Traffic during each Year, and the proportion remaining to be completed at the end of 1852; also, showing the Total Length of Railway opened for Traffic in each Year since 1843.

| — | | LENGTH OF LINE OPENED. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Previously to December, 1843. | During 1844. | During 1845. | During 1846. | During 1847. | During 1848. | During 1849. | During 1850. | During 1851. | During 1852. | Total Length of Line opened to December, 1852. | Length of Line authorised at end of 1843, and during each subsequent year. | Decrease by Abandonment, Deviation, &c., under authority of subsequent Acts. | Length of Line after Reductions made in consequence of Abandonment, Deviation, &c., under the authority of Acts passed subsequent to 1843. | Length of Line remaining to be made. |
| Of Lines authorised previously to December, 1843 | | 2036 | 204 | 131 | 16 | 2 | 1 | .. | .. | .. | .. | 2390 | 2390 | .. | 2390 | .. |
| Of Lines authorised in | 1844 | .. | .. | 159 | 366 | 142 | 118 | 3 | 4 | .. | .. | 792 | 805 | .. | 805 | 13 |
| | 1845 | .. | .. | 6 | 224 | 573 | 604 | 311 | 213 | 65 | 106 | 2102 | 2700 | 33 | 2667 | 565 |
| | 1846 | .. | .. | .. | .. | 84 | 403 | 501 | 379 | 122 | 288 | 1777 | 4538 | 478 | 4060 | 2283 |
| | 1847 | .. | .. | .. | .. | 2 | 56 | 45 | 26 | 71 | 10 | 210 | 1354 | 160 | 1194 | 984 |
| | 1848 | .. | .. | .. | .. | .. | .. | 7 | .. | 7 | 16 | 30 | 371 | 5 | 366 | 336 |
| | 1849 | .. | .. | .. | .. | .. | .. | 2 | 1 | .. | .. | 3 | 16 | .. | 16 | 13 |
| | 1850 | .. | .. | .. | .. | .. | .. | .. | 2 | 4 | .. | 6 | 8 | .. | 8 | 2 |
| | 1851 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 15 | 15 | 135 | .. | 135 | 120 |
| | 1852 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 11 | 11 | 244 | .. | 244 | 233 |
| Total | | 2036 | 204 | 296 | 606 | 803 | 1182 | 869 | 625 | 269 | 446 | 7336 | 12561 | 676 | 11835 | 4549 |

24. Nothing in the progressive development of this vast national enterprise is more surprising than the amount of capital raised and expended upon it, and the rapidity and facility with which it was obtained.

The following statement, also taken from the official reports, will illustrate this:—

| | | |
|---|---|---|
| Total capital raised by shares and loans up to the end of 1848. | | £200,173058 |
| Total capital similarly raised in | 1849. | 29,574720 |
| Ditto. | 1850. | 10,522967 |
| Ditto. | 1851. | 7,970151 |
| Total capital raised up to the end of 1851 | | £248,240896 |

Of the sum of 248 millions, which had been expended before the 1st January, 1852, a part had been absorbed by the lines which were in process of construction, but had not yet been opened. Against this, however, there remained an amount of capital still to be expended on the lines already open. On most of the more recently opened railways, the stations were still incomplete; in some cases, depots, workshops, and other permanent buildings had not even been commenced. The full complement of the locomotive and rolling stock had not been provided. In the absence of exact data then, if these latter expenses be placed against the former, the entire capital of 248 millions may be placed to the account of 7336 miles open for traffic; which would give an average expense of construction, including the locomotive and carrying stock, and the workshops and depots for its repair, &c., of 33840*l.* per running mile.

25. The extent to which these enterprises employed the industry of the country may be judged from the following results of the reports:—

It appears that in 1848 a quarter of a million of persons were employed on the railways of the United Kingdom; and if it be considered that each of these must have contributed to the support, on an average, of one or more other persons, it will follow, that this vast enterprise must have, at that epoch, supplied means of living to at least two per cent. of the entire population of these countries.

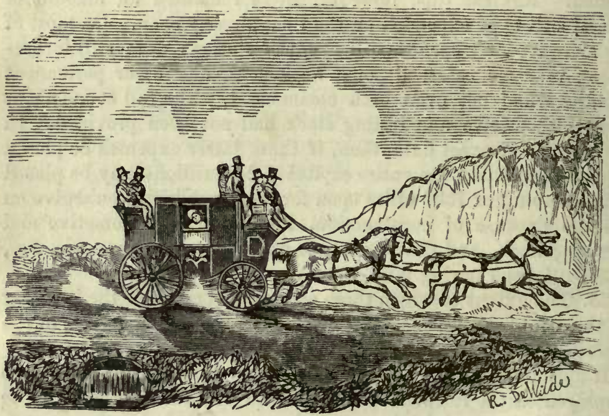
It further appears that, on the 30th June, 1852, there were employed

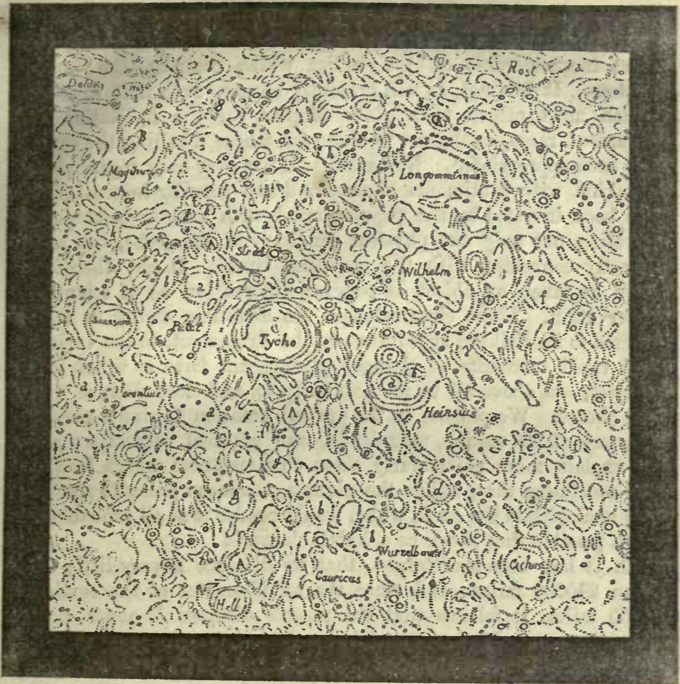
| | |
|---|---|
| On the railways open for traffic | 67601 |
| On the railways in progress of construction | 35935 |
| | 103536 |

It follows, therefore, that from 1848, to June, 1852, about

150000 persons have been dismissed from the direct employment of the railway companies, and who must now be obtaining support from other occupations. It is, however, certain that a large increase of the demand for labour has been produced by the creation and operation of railway traffic, such as that which arises and must arise from the establishment of founderies, carriage, and engine building, and other branches of railway business, not only in the United Kingdom, but in other countries which are to a great extent supplied by British industry.

We shall on another occasion notice the progress of locomotion by railway in other countries.






TELESCOPIC VIEW OF THE REGION OF THE MOON SURROUNDING THE CIRCULAR MOUNTAIN CHAIN CALLED TYCHO, MEASURING ABOUT 375 MILES NORTH AND SOUTH, AND ABOUT 200 MILES EAST AND WEST.

# THE MOON.

1. Interest with which the moon is regarded, and influences with which it has been invested by the popular mind.—2. Its distance.—3. Its orbit.—4. Its magnitude.—5. Its rotation.—6. Conjunction.—7. Quadrature.—8. Opposition.—9-11. Tests of an atmosphere.—12-13. None exists on the moon.—14. No liquids.—15. No diffusion of solar light.—16. Appearance of earth seen from moon.—17. It would have belts.—18. Geographical features and its rotation would be visible through the clouds.—19. Moonlight neither warm nor cold.—20. Moon's physical condition.—21. Thickly covered with mountains.—22. Selenographical discoveries of Beer and Mädler.—23. Vast extent and diameter of the lunar mountains.—24. Circular chains.—25. Description of Tycho. — 26. Heights of lunar mountains.—27. Observations of Lord Rosse.—28. Moon not inhabited.

1. Estimated merely by its magnitude, the moon is among the most inconsiderable of the bodies which compose the Solar System. It has not, as will presently appear, even that interest which must attach to a globe adapted for the habitation of organised races, analogous to those for whose dwelling the earth has been appropriated. Nevertheless it has ever been regarded by mankind with sentiments of profound and peculiar interest, and has been invested by the popular mind with various influences, affecting not only the physical condition of the globe, but also directly connected with the organised world. It has therefore been as much an object of popular superstition as of scientific observation. These circumstances are doubtless owing in some degree to its striking appearance in the firmament, to the various and rapid succession of changes of apparent form to which it is subject, and above all to its proximity to, and close alliance with our planet. We propose on the present occasion to give a general account of its motion, magnitude, and physical condition; and to explain more particularly those circumstances which lead to the conclusion that, unlike the planets, the moon presents none of the analogies to the earth which would render it at all probable or even possible that it can be a habitable world.

2. It has been ascertained, that its distance is very little less than 240000 miles; and since the semidiameter of the earth is 4000 miles, it follows that the moon's distance is about sixty semidiameters of the earth. The method of ascertaining this distance differs in nothing that is essential, from that by which a common surveyor ascertains the distance of an object on the earth which is inaccessible to him.

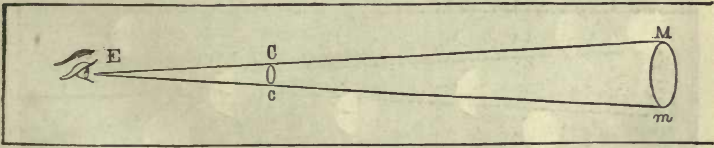
3. Now the least reflection will render it apparent that the moon must move round the earth, in a path which cannot differ much from a circle of which the earth is the centre. This follows from the fact with which every one is familiar, that its apparent magnitude is always nearly the same. It is, therefore, always at the same or nearly the same distance from the observer. The earth must consequently be placed in the centre of its path, and that path must be nearly a circle.

4. When the distance of a visible object is determined, its magnitude may easily be ascertained by comparing it with any other object of known magnitude at a known distance. Let us take, for example, a halfpenny, which measures about an inch in diameter, and let it be placed between the eye and the moon. It will be found on the first trial that the coin will appear larger than the moon; it will, in fact, completely conceal the moon from the eye, and produce what may be termed a total eclipse of that luminary. Let the coin be moved however further from the eye,

and it will apparently diminish in size as its distance is increased. Let it be removed until it becomes equal in apparent magnitude to the moon, so that it will exactly cover the moon, and neither more nor less. If its distance be then measured, it will be found to be about 120 inches, or 240 half inches. But it is known that the distance of the moon is about 240000 miles, and consequently it follows in this case, that 1000 miles in the moon's distance is exactly what half an inch is in the coin's distance. Now under the circumstances here supposed, the coin and the moon are similar objects of equal apparent magnitude. In fact the coin is another moon on a smaller *scale*, and we may use the coin to measure the moon's distance, provided we know the *scale*, exactly as we use the space upon a map of any known scale to measure a country. But it has been just stated that the *scale* is in this case half an inch to 1000 miles; since, then, the coin measures two half inches in diameter, the moon must measure 2000 miles in diameter. The moon is then a globe whose diameter is about one-fourth of that of the earth.

This may be rendered still more clear by reference to the annexed diagram (fig. 1), where E is the eye, C the coin, and M the moon. It will be evident on mere inspection, that the triangle formed by the distance EC of the coin from the eye, and the diameter Cc of the coin, is similar to the triangle formed by the distance EM of the moon from the eye and the diameter M*m* of the moon, and that consequently the proportion of EC to Cc is exactly the same as that of EM to M*m*. But as has just been stated, it is found that when Cc exactly covers the moon, and neither more nor less than covers it, EC is 120 times Cc. It follows, therefore, that EM is 120 times M*m*. But since it has been ascertained that EM is 240000 miles, that is 120 times 2000 miles, it follows that M*m* is 2000 miles.

Fig. 1.



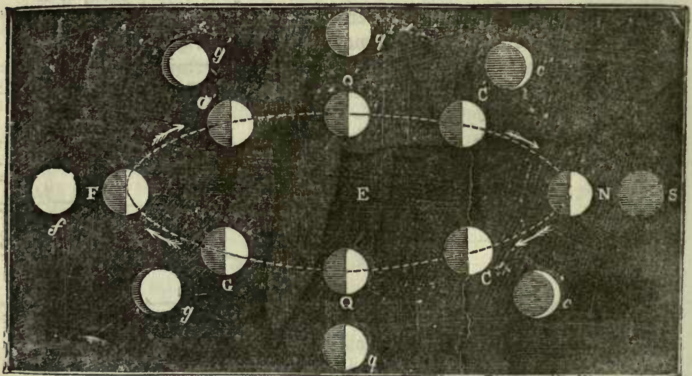

5. While the moon moves around the earth, we find by observations of its appearance, that the same hemisphere is always turned toward us. We recognise this fact by observing that the same marks always remain in the same place upon it. Now, in order that a globe which revolves around a centre should turn continually the same hemisphere toward that centre, it is necessary that

it should make one revolution upon its axis in the time it takes so to revolve. For let us suppose that, in any one position, it has the centre round which it revolves north of it, the hemisphere turned toward the centre is turned toward the north. After it makes a quarter of a revolution, the centre is to the west of it, and the hemisphere which was previously turned to the north must now be turned to the west. After it has made another quarter of a revolution the centre will be south of it, and it must be now to the south. In the same manner, after another quarter of a revolution, it must be turned to the east. As the same hemisphere is successively turned to all the points of the compass in one revolution, it is evident that the globe itself must make a revolution on its axis in that time.

It appears, then, that the rotation of the moon upon its axis being equal to that of its revolution in its orbit, is 27 days, 7 hours, and 44 minutes. The intervals of light and darkness to the inhabitants of the moon, if there were any, would then be altogether different from those provided in the planets; there would be about 13 days of continued light alternately with 13 days of continued darkness; the analogy, then, which prevails among the planets with regard to days and nights, and which forms a main argument in favour of the conclusion that they are inhabited globes like the earth, does not hold good in the case of the moon.

6. While the moon revolves round the earth, its illuminated

Fig. 2.




hemisphere is always presented to the sun; it therefore takes various positions in reference to the earth. The effects of this are exhibited in the annexed fig. 2. Let E S represent the direction of the sun, and E the earth; when the moon is at N, between the sun and the earth, its illuminated hemisphere being turned toward the sun, its dark hemisphere will be presented toward the earth; it will therefore be invisible. In this position the moon is said to be in CONJUNCTION.

When it moves to the position C, the enlightened hemisphere being still presented to the sun, a small portion of it only is turned to the earth, and it appears as a thin crescent, as represented at *c*.

7. When the moon takes the position of Q, at right angles to the sun, it is said to be in QUADRATURE: one half of the enlightened hemisphere only is then presented to the earth, and the moon appears halved as represented at *q*.

When it arrives at the position G, the greater part of the enlightened portion is turned to the earth, and it is gibbous, appearing as represented at *g*.

8. When the moon comes in OPPOSITION to the sun, as seen at F, the enlightened hemisphere is turned full toward the earth, and the moon will appear full as at *f*, unless it be obscured by the earth's shadow, which rarely happens. In the same manner it is shown that at G′ it is again gibbous; at Q′ it is halved, and at C′ it is a crescent.

If the moon or the planets be supposed to be viewed by an observer placed on the one side or the other of the general plane in which they move, they will appear to move either in the direction of the hands of a clock, or in the contrary direction, according to the side of the general plane from which they are seen. If the observer be supposed to be on the north side of that plane, their motion will be contrary to that of the hands of a clock. If he is placed on the south side of that plane, their motion will be in the direction of the hands of a clock.

In the case represented in fig. 2, and also in the astronomical diagrams in the first volume of the Museum, pp. 5, 11, &c., the observer is supposed to be placed at the south side of the general plane.

9. In order to determine whether or not the globe of the moon is surrounded with any gaseous envelope like the atmosphere of the earth, it is necessary first to consider what appearances such an appendage would present, seen at the moon's distance, and whether any such appearances are discoverable.

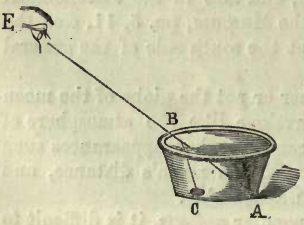
10. According to ordinary and popular notions, it is difficult to separate the idea of an atmosphere from the existence of clouds; yet to produce clouds something more is necessary than air. The presence of water is indispensable, and if it be assumed that no water exist, then certainly the absence of clouds is no proof of the

absence of an atmosphere. Be this as it may, however, it is certain that there are no clouds upon the moon, for if there were, we should immediately discover them, by the variable lights and shadows they would produce. If there be an atmosphere upon the moon, it is therefore one entirely unaccompanied by clouds.

11. One of the effects produced by a distant view of an atmosphere surrounding a globe, one hemisphere of which is illuminated by the sun, is, that the boundary, or line of separation between the hemisphere enlightened by the sun and the dark hemisphere, is not sudden and sharply defined, but is gradual—the light fading away by slow degrees into the darkness. It is to this effect upon the globe of the earth that twilight is owing, and as we shall see hereafter, such a gradual fading away of the sun's light is discoverable on some of the planets, upon which an atmosphere is observed. Now, if such an effect of an atmosphere were produced upon the moon, it would be perceived by the naked eye, and still more distinctly with the telescope. When the moon appears as a crescent, its concave edge is the boundary which separates the enlightened from the dark hemisphere. When it is in the quarters, the diameter of the semicircle is also that boundary. In neither of these cases, however, do we ever discover any gradual fading away of the light into the darkness; on the contrary, the boundary, through serrated and irregular, is nevertheless perfectly well defined and sudden. All these circumstances conspire to prove that there does not exist upon the moon an atmosphere capable of refracting light in any sensible degree.

But it may be contended that an atmosphere may still exist, though too attenuated to produce a sensible twilight. Astronomers, however, have resorted to another test of a much more decisive and delicate kind, the nature of which will be understood by explaining a simple principle of optics. When a ray of light passes through a transparent medium, such as air, water, or glass, it is generally deflected from its rectilinear course, so as to form an angle. A simple and easily-executed experiment will render this intelligible. Let a visible object, such as a coin, be placed at C, in the bottom of a bucket. Let the eye be placed at E (fig. 3), so that the side of the bucket, when empty, shall just conceal the coin, and so that the nearest point to the coin visible shall be at A, in the direction of the line E B A. Let the bucket be now filled with water, and the

Fig. 3.

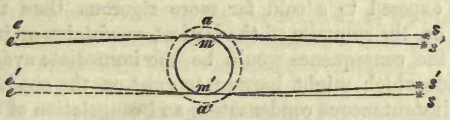


coin will become immediately visible; the reason of which is, that the ray of light C B proceeding from the coin is bent at an angle in passing from the water into the air, and reaches the eye by the angular course C B E. Thus it appears that the coin will be visible to the eye, notwithstanding the interposition of the opaque side of the bucket.

Let us see how this principle can be applied to the case of the moon's atmosphere, if such there be.

Let *m m′* (fig. 4) represent the disk of the moon. Let *a a′* represent the atmosphere which surrounds it. Let *s m e* and *s m′ e* represent two lines touching the moon at *m* and *m′*, and proceeding towards the earth. Let *s s* be two stars seen in the direction of these lines. If the moon had no atmosphere, these stars would appear to touch the edge of the moon at *m* and *m′*, because the rays of light from them would pass directly toward the earth; but if the moon have an atmosphere, then that atmosphere will possess the property which is common to all transparent media of refracting light, and, in virtue of such pro-

Fig. 4.




perty, stars in such positions as *s′ s′*, behind the edge of the moon, would be visible at the earth, for the ray *s′ m*, *s′ m′*, in passing through the atmosphere, would be bent at an angle in the direction *m e′*, and *m′ e′*, so that the stars *s′ s′* would be visible at *e′ e′*, notwithstanding the interposition of the edges of the moon.

This reasoning leads to the conclusion that as the moon moves over the face of the firmament, stars will be continually visible at its edge which are really behind it if it have an atmosphere, and the extent to which this effect will take place will be in proportion to the density of the atmosphere.

12. The magnitude and motion of the moon and the relative positions of the stars are so accurately known that nothing is more easy, certain, and precise, than the observations which may be made with the view of ascertaining whether any stars are ever seen which are sensibly behind the edge of the moon. Such observations have been made, and no such effect has ever been detected. This species of observation is susceptible of such extreme accuracy, that it is certain that if an atmosphere existed upon the

moon a thousand times less dense than our own, its presence must be detected.

13. The earth's atmosphere supports a column of 30 inches of mercury: an atmosphere 1000 times less dense would support no more than the thirtieth of an inch. It may therefore be considered as proved that the space around the surface of the moon is as exempt from an atmosphere as is the receiver of a good air-pump after that instrument has exhausted it of air to the utmost limit of its power. In fine for all practical purposes it is demonstrated that the moon has no atmosphere.

14. The same physical tests which show the non-existence of an atmosphere of air upon the moon are equally conclusive against an atmosphere of vapour. It might, therefore, be inferred that no liquids can exist on the moon's surface, since they would be subject to evaporation. Sir John Herschel, however, ingeniously suggests that the non-existence of vapour is not conclusive against evaporation. One hemisphere of the moon being exposed continuously for 328 hours to the glare of sunshine of an intensity greater than a tropical noon, because of the absence of an atmosphere and clouds to mitigate it, while the other is for an equal interval exposed to a cold far more rigorous than that which prevails on the summits of the loftiest mountains or in the polar regions, the consequence would be the immediate evaporation of all liquids which might happen to exist on the one hemisphere, and the instantaneous condensation and congelation of the vapour on the other. The vapour would, in short, be no sooner formed on the enlightened hemisphere than it would rush to the vacuum over the dark hemisphere, where it would be instantly condensed and congealed, an effect which Herschel aptly illustrates by the familiar experiment of the CRYOPHOROUS. The consequence, as he observes, of this state of things would be absolute aridity below the vertical sun, constant accretion of hoar frost in the opposite region, and perhaps a narrow zone of running waters at the borders of the enlightened hemisphere. He conjectures that this rapid alternation of evaporation and condensation may to some extent preserve an equilibrium of temperature, and mitigate the severity of both the diurnal and nocturnal conditions of the surface. He admits nevertheless. that such a supposition could only be compatible with the tests of the absence of a transparent atmosphere even of vapour within extremely narrow limits; and it remains to be seen whether the general physical condition of the lunar surface as disclosed by the telescope be not more compatible with the supposition of the total absence of all liquid whatever.

It appears to have escaped the attention of those who assume the possibility of the existence of water in the liquid state on the moon, that, in the absence of an atmosphere, the temperature must necessarily be, not only far below the point of congelation of water, but even that of most other known liquids. Even within the tropics, and under the line with a vertical sun, the height of the snow line does not exceed 16000 feet, and nevertheless at that elevation, and still higher, there prevails an atmosphere capable of supporting a considerable column of mercury. At somewhat greater elevations, but still in an atmosphere of very sensible density, mercury is congealed. Analogy, therefore, justifies the inference that the total, or nearly total, absence of air upon the moon is altogether incompatible with the existence of water, or probably any other body in the liquid state, and necessarily infers a temperature altogether incompatible with the existence of organised beings in any respect analogous to those which inhabit the earth.

But another conclusive evidence of the non-existence of liquids on the moon is found in the form of its surface, which exhibits none of those well understood appearances which result from the long-continued action of water. The mountain formations with which the entire visible surface is covered are, as will presently appear, universally so abrupt, precipitous, and unchangeable, as to be utterly incompatible with the presence of liquids.

15. The general diffusion of the sun's light upon the earth is mainly due to the reflection and refraction of the atmosphere, and to the light reflected by the clouds; and without such means of diffusion the solar light would only illuminate those places into which its rays would directly penetrate. Every place not in full sunshine, or exposed to some illuminated surface, would be involved in the most pitchy darkness. The sky at noon-day would be intensely black, for the beautiful azure of our firmament in the day-time is due to the reflected colour of the air. Thus it appears that the absence of air on the moon must deprive the sun's illuminating and heating agency of nearly all its utility.

16. If the moon were inhabited, observers placed upon it would witness celestial phenomena of a singular description, differing in many respects from those presented to the inhabitants of our globe. The heavens would be perpetually serene and cloudless. The stars and planets would shine with extraordinary splendour during the long night of 328 hours. The inclination of her axis being only 5°, there would be no sensible changes of season. The year would consist of one unbroken monotony of equinox. The inhabitants of one hemisphere would never see the earth: while the inhabitants of the other would have it constantly in their firmament by day and by night, and always in the same position.

To those who inhabit the central part of the hemisphere presented to us, the earth would appear stationary in the zenith, and would never leave it, never rising nor setting, nor in any degree changing its position in relation to the zenith or horizon. To those who inhabit places intermediate between the central part of that hemisphere and those places which are at the edge of the moon's disk, the earth would appear at a fixed and invariable distance from the zenith, and also at a fixed and invariable azimuth, the distance from the zenith being everywhere equal to the distance of the observer from the middle point of the hemisphere presented to the earth. To an observer at any of the places which are at the edge of the lunar disk, the earth would appear perpetually in a fixed direction on the horizon.

The earth shone upon by the sun would appear as the moon does to us; but with a disk having an apparent diameter greater than that of the moon in the ratio of 79 to 21, and an apparent superficial magnitude about fourteen times greater, and it would consequently have a proportionately illuminating power.

*Earth light* at the moon would, in fine, be about fourteen times more intense than *moonlight* at the earth. The earth would go through the same phases and complete the series of them in the same period as that which regulates the succession of the lunar phases, but the corresponding phases would be separated by the interval of half a month. When the moon is *full* to the earth, the earth is *new* to the moon, and *vice versâ:* when the moon is a crescent, the earth is gibbous, and *vice versâ.*

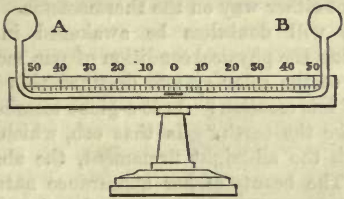
17. The features of light and shade would not, as on the moon, be all permanent and invariable. So far as they would arise from the clouds floating in the terrestrial atmosphere they would be variable. Nevertheless, their arrangement would have a certain relation to the equator, owing to the effect of the prevailing atmospheric currents parallel to the line. This cause would produce streaks of light and shade, the general direction of which would be at right angles to the earth's axis, and the appearance of which would be in all respects similar to the BELTS which are observed upon some of the planets, and which are ascribed to a like physical cause.

18. Through the openings of the clouds the permanent geographical features of the surface of the earth would be apparent, and would probably exhibit a variety of tints according to the prevailing characters of the soil, as is observed to be the case with the planet Mars even at an immensely greater distance. The rotation of the earth upon its axis would be distinctly observed and its time ascertained. The continents and seas would disappear in succession at one side and reappear at the other, passing across the disk of the earth as carried round by the diurnal rotation.

19. It has long been an object of inquiry among philosophers whether the light of the moon has any heat, but the most delicate experiments and observations have failed to detect this property in it. A thermometer of extreme sensibility, called a differential thermometer, was the instrument applied to this inquiry.

This instrument consists of two glass bulbs, A and B (fig. 5), connected by a rectangular glass tube. In the horizontal part of the tube a small quantity of coloured liquid (sulphuric acid, for example) is placed. Atmospheric air is contained in the bulbs and tube, separated into two parts by the liquid. The instrument is so adjusted that, when the drop of liquid is at the middle of the horizontal tube, the air in the bulbs has the same pressure; and having equal volumes, the quantities at each side of the liquid are necessarily equal. If the bulbs be affected by different temperatures, the liquid will be pressed from that side at which the

Fig. 5.




temperature is greatest, and the extent of its departure from the zero or middle is indicated by the scale. This thermometer is sometimes varied in its form and arrangement, but the principle remains the same. Its extreme sensitiveness, in virtue of which it indicates changes of temperature too minute to be observed by common thermometers, renders it extremely valuable as an instrument of scientific research. By this instrument, changes of temperature not exceeding the 6000th part of a degree are rendered sensible.

The light of the moon was collected into the focus of a concave mirror of such magnitude as would have been sufficient, if exposed to the sun's light, to evaporate gold or platinum. The bulb of the differential thermometer was placed in its focus, so as to receive upon it the concentrated rays of the moon. Yet no sensible effect was produced upon the thermometer. We must therefore conclude that the light of the moon does not possess the calorific property in any sensible degree.

This result will create less surprise when the comparative intensity of sunlight and moonlight are considered. It may be assumed, without sensible error, that the intensity of the sun's light on the surface of the moon and on the earth is the same; it follows from this, that supposing no light whatever to be absorbed by the moon, but the entire light of the sun to be reflected from its surface undiminished, the intensity of moonlight at the earth would bear to the intensity of sunlight the same proportion as the magnitude of the moon bears to the magnitude of the entire firmament, that is, the proportion very nearly of 1 to 300000; but there is no reflecting surface, however perfect, which does not absorb the light incident upon it in a very considerable degree, and the rugged surface of the moon must be a most imperfect reflector. It may then be considered as demonstrated that the intensity of moonlight is much more than 300000 times more feeble than that of sunlight. We shall not, then, be surprised at the absence of its heating power.

But if the rays of the moon be not warm, the vulgar impression that they are cold is equally erroneous. We have seen that they produce no effect either way on the thermometer.

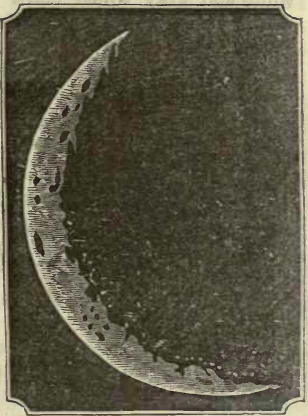
20. Curiosity will doubtless be awakened in a very lively manner regarding the physical condition of our moon: what part has the Maker of the solar system destined this body to play in the economy of His creation? Is it a globe teeming with life and organisation like the earth? Is that orb, which rolls in silent majesty through the midnight firmament, the abode of life and intelligence? The beauty of her appearance naturally leads the mind to conjectures of this kind. Yet the circumstances which I have unfolded regarding the total absence of air and water appear to exclude the possibility of any such supposition. How, may it be asked, can it be conceived that a globe can have upon it an organised world which is destitute of fluid matter in every form? How can growth, which implies gradual change, increase, and diminution, and all the various effects in which fluidity is an agent, go on there? How can they proceed upon such a solid, arid, unchangeable, crude mass? Let it be remembered what a multitude of purposes in our natural and social economy are subserved by the combination of the water and the atmosphere of our globe. None of these purposes can be fulfilled upon the moon. Perhaps, however, our notions on such questions may be cleared up to some extent by a careful examination of the facts that scientific research has collected respecting the physical condition of the surface of our satellite.

21. If, when the moon is a crescent, we examine with a telescope, even of moderate power, the concave boundary which is that part of the lunar surface where the enlightened hemisphere

ends and the dark hemisphere begins, we shall find that it is not an even and regular curve, which it undoubtedly would be if the surface of the globe of the moon were smooth and regular, or nearly so. If, for example, the lunar surface resembled in its general characteristics that of our globe; granting the total absence of water, and that the entire surface is land, but that land had the general characteristics of the continents of the globe of the earth; then I say, that the inner boundary of the lunar crescent would still be a regular curve, broken or interrupted only at particular points. Where great mountain ranges, like those of the Alps, the Andes, or the Himalaya, might chance to cross it, these lofty peaks would project vastly-elongated shadows along the adjacent plain; for it will be remembered that, being situated at the moment in question at the boundary of the enlightened and darkened hemispheres, the shadows would be those of evening and morning; which are prodigiously longer than the objects themselves. The effects of these would be to cause gaps or irregularities in the general outline of the inner boundary of the crescent; with these rare exceptions, the inner boundary of the crescent produced by a globe like the earth would be an even and regular curve.

Such, however, is not the case with the inner boundary of the lunar crescent, even when viewed by the naked eye, and still less so when magnified by a telescope. It is found, on the contrary, rugged and serrated, and brilliantly illuminated points are seen in the dark parts at some distance from it, while dark shadows of considerable length appear to break into the illuminated surface. The inequalities thus apparent indicate singular characteristics of the surface. The bright points seen within the dark hemisphere are the peaks of lofty mountains tinged with the sun's light. They are in the condition with which all travellers in Alpine countries are familiar; after the sun has set, and darkness has set in over the valleys at the foot of the chain, the sun still continues to illuminate the peaks above. The sketch (fig. 6), of the lunar crescent, will illustrate these observations.

Fig. 6.



22. The visible hemisphere of our satellite has, within the last quarter of a century, been subjected to the most rigorous examination which unwearied industry, aided by the vast improvement which has been effected in the instruments of telescopic observation, rendered possible; and it is no exaggeration to state that we now possess a chart of that hemisphere, which in accuracy of detail far exceeds any similar representation of the earth's surface.

Among the selenographical observers, the Prussian astronomers, MM. Beer and Mädler, stand pre-eminent. Their descriptive work, entitled "Der Monde," contains the most complete collection of observations on the physical condition of our satellite, and the chart, measuring 37 inches in diameter, exhibits the most complete representation of the lunar surface extant. Besides this great work, a selenographic chart was produced by Mr. Russel, from observations made with a seven-foot reflector, a similar delineation by Lohrmann, and, in fine, a very complete model in relief of the visible hemisphere by Madame Witte, a Hanoverian lady.

23. The surface of the visible hemisphere is thickly covered with mountainous masses and ranges of various forms, magnitudes, and heights, in which, however, the prevalence of a circular or crater-like form is conspicuous. The various tints of white and gray which mark the lineaments observed upon the disk arise partly from the different reflecting powers of the matter composing different parts of the lunar surface, and partly from the different angles at which the rays of the solar light are incident upon them. The more intensely white parts are mountains of various magnitude and form, whose height, relatively to the moon's magnitude, greatly exceeds that of the most stupendous terrestrial eminences; and there are many characterised by an abruptness and steepness which sometimes assume the position of a vast vertical wall, altogether without example upon the earth. These are generally disposed in broad masses, lying in close contiguity, and intersected with vast and deep valleys, gullies, and abysses, none of which, however, have any of the characters which betray the agency of water.

24. There are circular areas, varying from 40 to 120 miles in diameter, enclosed by a ring of mountain ridges, mostly continuous, but in some cases intersected at one or more points by vast ravines. The enclosed area is generally a plain on which mountains of less height are often scattered. The surrounding circular ridge also throws out spurs, both externally and internally, but the latter are generally shorter than the former. In some cases, however, internal spurs, which are diametrically opposed, unite

in the middle so as to cut in two the enclosed plain. In some rare cases the enclosed plain is uninterrupted by mountains, and it is almost invariably depressed below the general level of the surrounding land. A few instances are presented of the enclosed plain being convex.

The mountainous circle enclosing these vast areas is seldom a single ridge. It consists more generally of several concentric ridges, one of which, however, always dominates over the rest, and exhibits an unequal summit, broken by stupendous peaks, which here and there shoot up from it to vast heights. Occasionally it is also interrupted by smaller mountains of the circular form.

25. The most remarkable of the class of lunar mountains, called ring mountains, is that called TYCHO. This object is distinguishable without a telescope on the lunar disk when full; but, owing to the multitude of other features which become apparent around it in the phases, it can then be only distinguished by a perfect knowledge of its position, and with a good telescope. The enclosed area, which is very nearly circular, is 47 miles in diameter, and the inside of the enclosing ridge has the steepness of a wall. Its height above the level of the enclosed plain is 16000 feet, and above that of the external regions 12000 feet. There is a central mountain, having the height 4700 feet, besides a few lesser hills within the enclosure.

This region of the moon is represented in the engraving at the head of this tract, copied and reduced from the chart of MM. Beer and Mädler. The volcanic character observed in the mountain formations loses much of its analogy to like formations on the earth's surface when higher magnifying powers enable us to examine the forms of what appear to be craters, and to compare their dimensions with even the most extensive terrestrial craters. Numerous examples may be produced to illustrate this. Tycho, which, viewed under a moderate magnifying power, appears to possess in so eminent a degree the volcanic character, is, as has been stated, a circular chain enclosing an area of 47 miles in diameter. Gassendi, another system of like form, and of still more stupendous dimensions, as seen with high magnifying powers, consists of two enormous circular chains of mountains, the lesser, which lies to the north, measuring 16½ miles in diameter, and the greater, lying to the south, enclosing an area 60 miles in diameter. The area enclosed by the former is therefore 214, and by the latter 2827 square miles. The height of the lesser chain is about 10000 feet, while that of the greater varies from 3500 to 5000 feet. The vast area thus enclosed by the greater chain includes, at or near its centre, a principal central mountain, having eight peaks and an height of 2000 feet, while scattered over the surrounding enclosure upwards of a hundred mountains of less considerable elevation have been counted.

It is easy to see how little analogy to a terrestrial volcanic crater is presented by these characters.

26. In the work of Beer and Mädler a table of the heights of above 1000 mountains is given, several of which attain to an elevation of 23000 feet, equal to that of the highest summits of terrestrial mountains, while the diameter of the moon is little more than a fourth of that of the earth.

27. By means of the great reflecting telescope of Lord Rosse, the flat bottom of the crater called Albategnius is distinctly seen to be strewed with blocks, not visible with less powerful instruments; while the exterior of another (Aristillus) is intersected with deep gullies radiating from its centre.

28. In fine, the entire geographical character of the moon, thus ascertained by long-continued and exact telescopic surveys, leads to the conclusion that no analogy exists between it and the earth which would confer any probability on the conjecture that it fulfils the same purposes in the economy of the Universe, and we must infer that whatever be its uses in the solar system, or in the general purposes of creation, it is not a world inhabited by organised races, such as those to which the earth is appropriated.

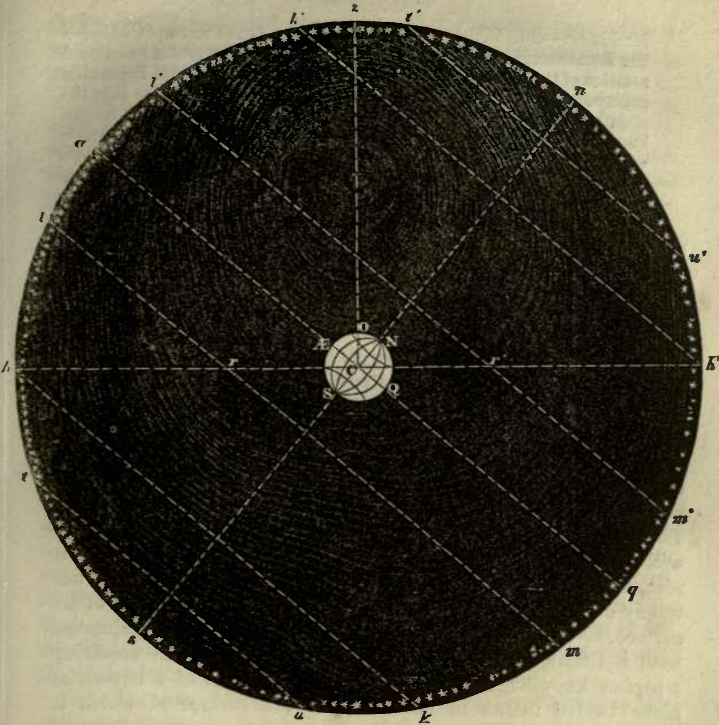


Fig. 2.

# COMMON THINGS.

## THE EARTH.

1. Difficulty of observing the earth as a whole.—2. It appears at first an indefinite flat surface.—3. This disproved by travelling round it.—4. Proof of the curvature of its surface by observation of distant objects at sea.—5. By the Earth's shadow projected on the Moon.—6. Inequalities of surface, such as mountains and valleys, insignificant.—7. Magnitude of Earth, how ascertained.—8. Length of a degree of latitude.—9-10. Illustrations of the Earth's magnitude.—11. Is the Earth at rest?—12. Apparent motion of the firmament.—13. Origin of the word "Universe."—14. This apparent motion may not be real—may arise from the rotation of the Earth.—15. How such a rotation would produce it.—16. Poles.—17. Equator.—18. Hemispheres.—19.

Meridians.—20. Which of the two rotations is the more probable?—21. Rotation of the universe impossible.—22. Simplicity of the supposed rotation of the globe.—23. Direct proofs of this motion.—24. Foucault's experiment.—25. Its analogy to the planets.—26. Conclusion as to the globular form of the earth requires modification.—27. All human knowledge tentative and approximative.—28. Rotation not compatible with the exact globular form.—29. Centrifugal force of the Earth's rotation.—30. The globe rotating would assume the form of an oblate spheroid.—31. The degree of ellipticity would vary with the velocity of rotation.—32. Experimental illustration.—33. Ellipticity corresponding to the diurnal rotation.—34. How these circumstances affect the actual state of the Earth.—35. Form of a terrestrial meridian.—36. Dimensions of the terrestrial spheroid.—37. Its departure from an exact globe very small.—38. Its density and mass.—39. Determined by Cavendish and Maskelyne.—40. Its total weight.

1. Locke somewhere observes, with his usual felicity of illustration, that the "mind, like the eye, while it makes us see and perceive all other things, can never turn its view with advantage upon itself." We encounter something similar to this in our researches through the universe; for of all the objects which compose it, one of the most difficult of which to obtain a complete and accurate knowledge is the planet which we inhabit. The cause of this is our proximity to it, and intimate connexion with it. We are confined upon its surface, from which we cannot separate ourselves. We cannot obtain a bird's-eye view of it, nor at any one time behold more than an insignificant portion of its surface. We have the same difficulty in obtaining an acquaintance with it that a microscopic animalcule would have in acquiring a perfect knowledge of the form and dimensions of a terrestrial globe twelve inches in diameter, on the surface of which it creeps.

Still, by a variety of indirect methods supplied by the ingenuity of scientific research, we have been enabled to ascertain its form, dimensions, and physical constitution, with a considerable degree of accuracy.

2. The first impression produced upon the eye of an observer, who has not carried his inquiries further, is, that the surface of the earth is a flat plane, interrupted only by the inequalities of the land. A little careful observation, however, upon the many phenomena which are easily accessible to every observer, will correct this erroneous impression.

3. It is well known that if a voyage were made upon the earth, continually preserving one and the same direction, or doing so as nearly as circumstances will permit, we should at length arrive at the place from which we departed. If the earth were an indefinite plane, this could not happen. It is evident, then, that whatever be the exact form of the earth, it is a body which is on

every side limited, and one which must therefore have such a surface that a traveller or navigator can completely surround it in one continuous course.

4. Let us see, however, whether we may not obtain evidence more distinct as to its form. If we stand on the deck of a ship at sea, and out of sight of land, the view being bounded only by sea and sky, and look at the horizon when a ship (A, fig. 1) approaches, we shall at first see its topmast rising out of the water like a pole.

Fig. 1.


As it gradually comes nearer to us (as at B), more of the mast will become visible, and the sails will be seen—cut off, however, horizontally, by the line at which the water and sky unite. Upon the nearer approach of the ship (as at C and D), the hull will at length become visible. Now since this takes place on all sides around us, it will follow that when the ship is at a distance, there must be *something* interposed between the eye and it which intercepts the view of it; but as the surface of the water is generally uniform, and not subject to sudden and occasional inequalities like that of the land, we can only imagine its general form to be convex, and that its convexity is interposed between the eye and the object so as to intercept the view.

Since the same effects are observed from whatever direction the ship may approach, it will follow that the same convexity must prevail on every side.

If, on the contrary, the surface extending from the eye to the ship were a plane, the ship would be rendered invisible only by reason of its distance; whereas it is ascertained that a ship frequently is invisible at a distance at which it must be seen but for the interposition of some other object; this may be tested, and in fact is frequently tested at sea by mounting to the masthead, whence the seaman being enabled to overlook the convexity, sees vessels which are invisible from the deck, although, strictly speaking, he is nearer to those vessels on the deck than at the masthead.

When the mariner, after completing a long voyage, discovers by his observations and reckonings that he is approaching the desired coast, he ascends to the topmast and looks out for the appearance of mountains or other elevated land, and he invariably sees them from that point long before they are visible from the deck. He afterwards sees them from the deck long before the general level of the country will be observed by him. All these are natural and necessary consequences of the convexity of the surface of the ocean. The same effects would be seen in any part of a continent which is sufficiently free from mountains and other inequalities.

5. But we have a still more conclusive and convincing proof of the general form of the earth even than those which have been explained. When the moon passes directly behind the earth, so that the shadow which the earth projects behind it in the direction opposite to the sun shall fall upon the moon, we invariably find that shadow to be, not as is commonly said, circular, but such exactly as one globe would project upon the surface of another globe. Now, as this takes place always, in whatever position the earth may be, and while the earth is revolving rapidly with its diurnal motion upon its axis, it follows that the earth must either be an exact globe or so little different from a globe that its deviation from that figure is undiscoverable in its shadow.

We may, then, consider it demonstrated that the earth may be practically regarded as globular in its form. We shall hereafter see that it slightly departs from the spherical figure, but our present purpose will be best answered by regarding it as a globe.

6. The objection will doubtless occur to many minds that the inequality which exists on the surface of that portion of the globe that is covered by land, especially the loftier ridges of mountains, such as the Andes, the Alps, the Himalaya, and others, are incompatible with the idea of a globular figure. If the term globular figure were used in the strictest geometrical sense, this objection doubtlessly would have great force. But let us see the real extent of this presumed deviation from the globular form. The highest mountain on the surface of the globe does not exceed five miles above the general level of the sea. The entire diameter of the globe, as we shall presently see, is eight thousand miles. The proportion, then, which the highest summit of the loftiest mountains bears to the entire diameter of the globe will be that of five to eight thousand, or one to sixteen hundred. If we take an ordinary terrestrial globe of sixteen inches in diameter, each inch upon the globe will correspond to five hundred miles upon the earth, and the sixteen hundredth part of its diameter, or the hundredth part of an inch, will correspond to five miles. If, then, we take a narrow strip of paper, so thin that it would take one hundred leaves to make an inch in thickness, and paste such a strip on the surface of the globe, the thickness of the strip would represent upon the sixteen-inch globe the height of the loftiest mountain on the earth. We are then to consider that the highest

mountain-ranges on the earth deprive it of its globular figure only in the same degree and to the same extent as a sixteen-inch globe would be deprived of its globular figure by a strip of paper pasted upon it the hundredth part of an inch thick.

It is supposed that the greatest depth of the ocean which covers any portion of the globe does not exceed the greatest height of the mountains upon the land. If this be true, the ocean upon the earth might be represented by a film of liquid laid with a camel's hair pencil upon the surface of a sixteen-inch globe.

It is apparent, therefore, that depths and heights which appear to the common observer to be stupendous, are nothing when considered with reference to the magnitude of the earth; and that, so far as they are concerned, we may practically regard the earth as a true globe.

7. Having ascertained satisfactorily the form of the earth, our next enquiry must be as to its magnitude; and since it is a globe, all that we are required to know is the length of its diameter.

If a line were described surrounding the globe, so as to form a circle upon it, the centre of which should be at the centre of the globe, such a circle is called a *great circle* of the earth. Now if we know the length of the circumference of such a circle, we could easily calculate the length of its diameter, for the proportion of the circumference to the diameter is exactly known. But we could calculate the circumference if we knew the length of one degree upon it, since we know that the circumference consists of three hundred and sixty degrees; we should therefore only have to multiply the length of one degree by three hundred and sixty to obtain the circumference, and should thence calculate the diameter.

8. In our tract upon latitudes and longitudes, it was shown how the latitude of a place can be ascertained. Now, let us suppose two places selected which are upon the same meridian of the earth, and therefore have the same longitude, and which are not very far removed from each other. Let them, moreover, be selected so that the distance between them can be easily and accurately measured. Now let the latitude of these two places be exactly determined, and let us suppose for example that the difference between these two latitudes is found to be one degree and a half; and supposing also that on measuring the distance between them, that distance is found to be one hundred and four miles and thirty-five hundredths. We should thence infer that such must be the length of one degree and a half of the earth's surface, and that consequently the length of one degree would be two thirds of this, or sixty-nine and a half miles. Having thus found the length of

a degree, we should have to multiply it by three hundred and sixty, by which we should obtain the circumference of the earth. This would give twenty-five thousand and twenty miles, and we should then find by the usual mode of calculation the diameter of the earth, which would prove to be a little under eight thousand miles.

The fact that a degree of the earth's circumference consists in round numbers of just so many thousand feet as there are days in the year, supplies a very convenient aid to the memory.

We have made these calculations chiefly with a view of rendering the principles of the investigation intelligible. The more exact dimensions of the earth will be explained hereafter.

We conclude, then, that the earth is a globe eight thousand miles in diameter.

9. To enounce this stupendous arithmetical result is much easier than to obtain any distinct notion of the actual magnitude which it expresses. Such a globe has a circumference of twenty-five thousand miles. A locomotive engine travelling incessantly night and day, at twenty-five miles an hour, would take about forty-two days to go round it.

10. When the diameter of a globe is known, its surface and volume or cubical bulk can be easily determined. To find the surface we have only to take three hundred and fourteen hundredths of the square of the diameter, and to find the volume, five hundred and twenty-four thousandths of the cube of the diameter. In this way we find that the surface of the earth measures two hundred millions of square miles, and that its cubical bulk is about two hundred and sixty thousand millions of cubic miles.

If the materials which form such a globe were built up in the form of a vertical column, the base of which would have the magnitude of England and Wales, its height would be nearly four and a half millions of miles!

11. Such being the dimensions of the globe we inhabit, we are next to consider what is its condition as to motion. Is it, as it appears, at rest? For several thousand years in the history of the human race, it was not only so considered, but he that would have ventured to call in question its stability and quiescence would have been deemed insane. Certain expressions in the sacred Scriptures being erroneously supposed to affirm its immobility, it was deemed heretical to deny it; and Galileo, who did so, was put to the torture by the ecclesiastical authorities of the day, and compelled to admit its quiescence. This verbal admission was, however, so utterly opposed to his convictions, that, on quitting the presence of the inquisitors, he stamped on the ground, and muttered the words, "It moves for all that."

12. A few hours' attentive contemplation of the firmament at night will enable any common observer to perceive, that although the stars are, relatively to each other, fixed, the hemisphere, *as a whole*, is in motion. Looking at the zenith, that is the point directly above our head, constellation after constellation will appear to pass across it, having risen in an oblique direction from the horizon at one side, and, after passing the zenith, descending on the other side to the horizon, in a direction similarly oblique. Still more careful and longer continued observation, and a comparison, so far as can be made by the eye, of the different directions successively assumed by the same object, creates a suspicion, which every additional observation strengthens, that the celestial vault has a motion of slow and uniform rotation round a certain diameter as an axis, carrying with it all the objects visible upon it, without in the least deranging their relative positions or disturbing their arrangement.

When these loose impressions of the senses are submitted to the more exact means of observation which are at the disposition of astronomers, it is found that all the appearances of the heavens, the rising and the setting of the stars, the sun and the moon, their apparent motion in ascending to, passing, and descending from, their several points of culmination, is that of a sphere revolving with an uniform motion round the diameter which is directed to the pole.

The world we inhabit therefore would, to judge from these phenomena, seem to be fixed in the centre of a hollow sphere of vast magnitude. On the concave surface of this hollow sphere thus surrounding us at an immeasurable distance all the stars appear to be placed. This sphere, carrying the whole creation upon it, appears to revolve round our world. It makes a complete revolution in twenty-four hours.* By this rotation, the diurnal appearances of the rising and setting of all the heavenly bodies are perfectly explained.

13. The ancients who, as has been stated, affirmed the reality of this motion of the celestial sphere, gave to the whole creation around the earth, the name UNIVERSE; from two words, UNUS, *one*, and VERSUM, *turning* or *rotation;* because they assumed that by an imaginary force, called the PRIMUM MOBILE, or *first impulse*, this rotatory motion had been imparted to the firmament, which ever afterwards retained it.

14. It is easy to perceive that the apparent diurnal rotation of the firmament round the earth may arise indifferently from either of two causes: 1st, from such a real rotation of the firmament

* More exactly $23^h\ 56^m\ 4{\cdot}09^s$, but for the present the cause of this difference need not be noticed.

once in twenty-four hours; 2ndly, from the rotation of the globe of the earth in the same time round that diameter which is in the direction of the axis round which the firmament appears to revolve.

There is absolutely no other supposition possible but one or other of these. The rejection of either necessarily throws us upon the adoption of the other.

But it may be required that we should show how the rotation of the earth upon an axis passing through the poles would cause the apparent diurnal rotation of the firmament.

15. Let us assume that the earth is a globe revolving uniformly on its axis in twenty-four hours. The universe around it is relatively stationary, and the bodies which compose it being at distances which mere vision cannot appreciate, appear as if they were situate on the surface of a vast celestial sphere in the centre of which the earth revolves. This rotation of the earth gives to the sphere the appearance of revolving in the contrary direction, as the progressive motion of a boat on a river gives to the banks an appearance of retrogressive motion; and since the apparent motion of the heavens is from east to west, the real rotation of the earth which produces that appearance must be from west to east.

How this motion of rotation explains the phenomena of the rising and setting of celestial objects is easily understood. An observer placed at any point upon the surface of the earth is carried round the axis in a circle in twenty-four hours, so that every side of the celestial sphere is in succession exposed to his view. As he is carried upon the side opposite to that in which the sun is placed, he sees the starry heavens visible in the absence of the splendour of that luminary. As he is turned gradually towards the side where the sun is placed, its light begins to appear in the firmament, the dawn of morning is manifested, and the globe continuing to turn, he is brought into view of the luminary itself, and all the phenomena of dawn, morning, and sunrise are exhibited. While he is directed towards the side of the firmament in which the sun is placed, the other bodies of inferior lustre are lost in the splendour of that luminary, and all the phenomena of day are exhibited. When by the continued rotation of the globe the observer begins to be turned away from the direction of the sun, that luminary declines, and at length disappears, producing all the phenomena of evening and sunset.

Such, in general, are the effects which would attend the motion of a spectator placed upon the earth's surface, and carried round with it by its motion of rotation. He is the spectator of a gorgeous diorama exhibited on a vast scale, the earth which forms his station being the revolving stage by which he is carried round, so as to view in succession the spectacle which surrounds him.

These appearances vary with the position assumed by the observer on this revolving stage; or, in other words, upon his situation on the earth, as will presently appear.

16. That diameter upon which it is necessary to suppose the earth to revolve in order to explain the phenomena is that which passes through the terrestrial poles.

17. If the globe of the earth be imagined to be cut by a plane passing through its centre at right angles to its axis, such a plane will meet the surface in a circle, which will divide it into two hemispheres, at the summits of which the poles are situate. This circle is called the TERRESTRIAL EQUATOR.

18. That hemisphere which includes the continent of Europe is called the NORTHERN HEMISPHERE, and the pole which it includes is called the NORTHERN TERRESTRIAL POLE; the other hemisphere being the SOUTHERN HEMISPHERE, and including the SOUTHERN TERRESTRIAL POLE.

19. If the surface of the earth be imagined to be intersected by planes passing through its axis, they will meet the surface in circles which, passing through the poles, will be at right angles to the equator. These circles are called TERRESTRIAL MERIDIANS, and will be seen delineated on any ordinary terrestrial globe.

These observations will be more clearly comprehended by reference to fig. 2, in which N is the north, and S the south pole of the earth, and Æ Q the equator. The firmament surrounding the earth is represented by the circle *n æ s q*. The axis S N of the earth being supposed to be prolonged to the heavens will meet the firmament at *n* and *s*, the celestial north and south poles; and in like manner the plane of the terrestrial equator Æ Q being continued to the heavens, will meet the firmament at *æ q*, the celestial equator.

If an observer be stationed at O, his zenith will be at *z*, and his horizon at *h h′*. As the globe revolves from west to east, the heavens will be successively brought into view on the east, and will disappear continually on the west.

20. Assuming then that all the diurnal changes of appearance presented by the firmament, the risings and settings of the sun, moon, and stars, and their varying appearance in different latitudes, admit of being explained with equal precision and completeness, either by supposing the universe to revolve daily round the earth, or the earth to revolve daily on its axis, the only question which remains to be decided is, which of these two suppositions is the more probable?

The fixity and absolute repose of the globe of the earth being assumed by the ancients as a physical maxim which did not even admit of being questioned, they perceived the inevitable character of the alternative which the apparent diurnal rotation of the heavens imposed upon them, and accordingly embraced the hypothesis, which now appears so monstrous, and which is implied in the term UNIVERSE, which they have bequeathed to us.

21. But with the knowledge which has been obtained by the labours of modern astronomers respecting the enormous magnitudes of the principal bodies of the physical universe, magnitudes compared with which that of the globe of the earth dwindles to a mere point, and their distances under the expression of which the very power of number itself almost fails, and recourse is had to colossal units in order to enable it to express even the smallest of them, the hypothesis of the immobility of the earth, and the diurnal rotation of the countless orbs of magnitudes so inconceivable filling the immensity of space once every twenty-four hours round this grain of matter composing our globe, becomes so preposterous that it is rejected, not as an improbability, but as an absurdity too gross to be even for a moment seriously entertained or discussed.

22. But if any ground for hesitation in the rejection of this hypothesis existed, all doubt would be removed by the simplicity and intrinsic probability of the only other physical cause which can produce the phenomena. The rotation of the globe of the earth upon an axis passing through its poles, with an uniform motion from west to east once in twenty-four hours, is a supposition against which not a single reason can be adduced based on improbability. Such a motion explains perfectly the apparent diurnal rotation of the celestial sphere. Being uniform and free from irregularities, checks, or jolts, it would not be perceivable by any local derangement of bodies on the surface of the earth, all of which would participate in it. Observers upon the surface of our globe would be no more conscious of it, than are the voyagers shut up in the cabin of a canal boat, or transported above the clouds in the car of a balloon.

23. It has been shown that a body descending from a great height does not fall in the true vertical line, which it would if the earth were at rest, but eastward of it, which it must, if the earth have a motion of rotation from west to east.

24. An ingenious expedient, by which the diurnal rotation of the earth is rendered visible, has been conceived and reduced to experiment by M. Leon Foucault. This contrivance is based upon the principle, that the direction of the plane of vibration of a pendulum is not affected by any motion of translation which may

be given to its point of suspension. Thus, if a pendulum suspended in a room and put into vibration in a plane parallel to one of the walls, be carried round a circular table, the plane of its vibration will continually be parallel to the same wall, and will therefore vary constantly in the angle it forms with the radius of the table which is directed to it.

Now, if a pendulum, suspended anywhere so near the pole of the earth that the circle round the pole may be considered a plane, be put in vibration in a plane passing through the pole, this plane, continuing parallel to its original direction as it is carried round the pole by the earth's rotation, will make a varying angle with the line drawn to the pole from the position it occupies. After being carried through a quarter of a revolution it will make an angle of 90° with the line to the pole, and so on. In fine, the direction of the pole will appear to be carried round the plane of vibration of the pendulum.

The same effects will be produced at greater distances from the pole, but the rate of variation of the angle under the plane of vibration and the plane of the meridian will be different, owing to the effects of the curvature of the meridian.

This phenomenon, therefore, being a direct effect of the rotation of the earth, supplies a proof of the existence of that motion, attainable without reference to objects beyond the limits of the globe.

25. Another evidence of the rotation of the earth upon its axis is derived from the ascertained fact that the planets which hold places in the solar system similar to that of the earth, do revolve on axes, in times not very different from that of the earth's rotation, as has been shown in our tract upon the Planets.

It may, then, be taken as proved that the earth is not fixed and quiescent, but that it has a rotatory motion round the diameter which passes through its poles, completing a revolution in a day.

26. Having explained the proofs by which we have arrived at the knowledge of the globular form of the earth, it may occasion some surprise that we shall now have to reconsider and modify that conclusion. In this there is nevertheless nothing unusual. It is quite in harmony with all the labours of those who devote themselves to the discovery of the laws of nature.

27. It is the condition of man, and probably of all other finite intelligences, to arrive at the possession of knowledge by the slow and laborious process of a sort of system of trial and error. The first conclusions to which, in physical enquiries, observation conducts us, are never better than very rough approximations to the truth. These, being submitted to subsequent comparison with the originals, undergo a first series of corrections, the more

prominent and conspicuous departures from conformity being removed. A second approximation, but still only an approximation, is thus obtained; and another and still more severe comparison with the phenomena under investigation is made, and another order of corrections is effected, and a closer approximation obtained. Nor does this progressive approach to perfect exactitude appear to have any limit. The best results of our intellectual labours are still only close resemblances to truth, the absolute perfection of which is probably reserved for a higher intellectual state.

These observations will be illustrated by the process of investigation and discovery in every department of physical science, but in none so frequently and so forcibly as in that which now occupies us.

The first conclusions at which we have arrived respecting the form of the earth is, that it is a globe; and with respect to its motion is, that it is in uniform rotation round one of its diameters, making one complete revolution daily.

28. The first question then which presents itself is, whether this form and rotation are compatible? It is not difficult to show, by the most simple principles of physics, that they are not; that with such a form such a rotation could not be maintained, and that with such a rotation such a form could not permanently continue.

The conclusion that the earth revolves on its axis with a motion corresponding to the apparent rotation of the firmament, is one which admits of no modification, and must from its nature be either absolutely admitted or absolutely rejected. The globular form imputed to the earth, however, has been inferred from observations of a general nature, unattended by any conditions of exact measurement, and which would be equally compatible with innumerable forms, departing to a very considerable and measurable extent from that of an exact geometrical sphere or globe.

29. It is a fact familiar to every one that when a body is whirled round in a circle it has a tendency to fly from the centre. This is called CENTRIFUGAL FORCE. If a stone be whirled round in a sling, this tendency is sensibly felt.

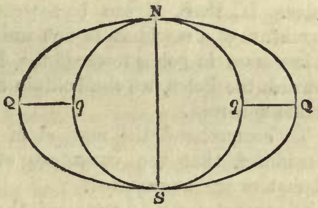
By reason of the rotation of the earth on its axis all the matter composing it, solid and fluid, being carried round the axis in circles of greater or less radius, has this tendency to fly from the axis round which it is thus whirled; and this tendency is stronger for those parts which are more distant than for those which are nearer to the common axis.

30. If the globe thus revolving were composed altogether of matter capable of yielding to the action of such forces, it would

obviously assume a form departing from that of an exact sphere. The parts near the equator would extend themselves to a greater distance from the axis, those more remote from the equator to a less distance, and so on, until, at the pole, the matter would not be at all affected by the rotation. This would be the case if the globe were formed of matter in a liquid or even in a semi-liquid or soft state, or if its materials were elastic.

The form it would take would be one resembling an orange or a turnip. Thus, if N S, fig. 3, be its axis, the equatorial diameter, *q q*, will be stretched out to the increased length, Q Q, while the parts between *q q* and the poles will be less and less extended the nearer they are to the poles, The globe would therefore be changed from the form N *q* S *q*. of a true sphere, to the form N Q S Q, of a flattened globe, called in geometry an OBLATE SPHEROID.

Fig. 3.




31. The elliptic form would depart more and more from a true circle as the motion of rotation is more rapid, so that between the time of rotation and the degree of ellipticity there is a fixed relation, such that when the time of rotation is given, the oval form, or what is the same, the proportion of the equatorial to the polar diameter, can be computed.

32. It is certain, then, that if the earth were composed of fluid, soft or elastic matter, it could not continue to retain the form of a globe, but would become a spheroid, having that degree of ellipticity which would correspond to a motion of rotation, at the rate of one revolution per day, and it is shown by calculation that this ellipticity would be such that the equatorial diameter would be greater than the polar diameter by one three-hundredth part.

33. But the earth, in its present state, is not composed of such yielding materials, and it becomes a question, what, in that case, must be the effect of the diurnal rotation on the distribution of land and water, if the earth were an exact globe.

34. The solid parts of the earth would resist by their cohesion the tendency of the rotation, to cause them to be accumulated and heaped up around the equator; but this would not be the case with the waters composing the seas and oceans. These, by reason of their freedom and mobility would yield to the centrifugal force, and would heap themselves up around the equator, flowing in that direction from the polar regions of either hemisphere, so that the necessary consequences of the earth having a form exactly

globular, and a diurnal rotation, would be that the surface would consist of two vast polar continents separated by an extensive equatorial ocean.

Such not being the distribution of land and water on the earth, it follows that its form cannot be that of an exact globe.

35. It remains, then, to find means to ascertain by direct measurement and observation, what is the actual form of the earth.

If a terrestrial meridian were an exact circle, as it would necessarily be if the earth were an exact globe, every part of it would have the same curvature. But if it were an ellipse, of which the polar diameter is the lesser axis, it would have a varying curvature, the convexity being greatest at the equator, and least at the poles. If, then, it can be ascertained by observation, that the curvature of a meridian is not uniform, but that on the contrary it increases in going towards the Line, and diminishes in going towards the Poles, we shall obtain a proof that its form is that of an oblate spheroid.

To comprehend the method of ascertaining this, it must be considered that the curvature of circles diminishes as their diameters are augmented.

If, therefore, a degree of the meridian be observed, and measured, at different latitudes, and it is found that its length is not uniformly the same as it would be if the meridian were a circle, but that it is less in approaching the equator, and greater in approaching the pole, it will follow that the convexity or curvature increases towards the equator, and diminishes towards the poles; and that consequently the meridian has the form, not of a circle, but of an ellipse, the lesser axis of which is the polar diameter.

Such observations have accordingly been made, and the lengths of a degree in various latitudes, from the Line to 66° N. and to 35° S., have been measured, and found to vary from 363000 feet on the Line to 367000 feet at lat. 66°.

From a comparison of such measurements, it has been ascertained that the equatorial diameter of the spheroid exceeds the polar by $\frac{1}{300}$th of its length.

Now this is precisely the form, precisely the degree of ellipticity, which a globe, composed of fluid or soft materials, would assume if it had a rotation on its axis once in twenty-four hours.

Thus it appears, that the form of the earth, ascertained by observation, supplies another proof of its diurnal rotation.

36. It is not enough to know the proportions of the earth. It is required to determine the actual dimensions of the spheroid. The following are the lengths of the polar and equatorial diameters,

according to the computations of the most eminent and recent authorities :—

| | BESSEL. | AIRY. |
|---|---|---|
| | Miles. | Miles. |
| Polar diameter . . . . . . | 7899·114 | 7899·170 |
| Equatorial diameter . . . . . | 7925·604 | 7925·648 |
| Absolute difference . . . . . | 26·471 | 26·478 |
| Excess of the equatorial expressed in a fraction of its entire length . . . | $\frac{1}{299 \cdot 407}$ | $\frac{1}{299 \cdot 330}$ |

The close coincidence of these results supplies a striking example of the precision to which such calculations have been brought.

37. The departure of the terrestrial spheroid from the form of an exact globe is so inconsiderable that, if an exact model of it turned in ivory were placed before us, we could not, either by sight or touch, distinguish it from a perfect billiard ball. A figure of a meridian actually drawn on paper could only be distinguished from a circle by the most precise measurement.

38. The magnitude of the earth being known with great precision, the determination of its mass and that of its mean density become one and the same problem, since the comparison of its mass with its magnitude will give its mean density, and the comparison of its mean density with its magnitude will give its mass.

The methods of ascertaining the mass or actual quantity of matter contained in the earth are all based upon a comparison of the gravitating force or attraction which the earth exerts upon an object with the attraction which some other body, whose mass is exactly known, exerts on the same object. It is assumed, as a postulate or axiom in physics, that two masses of matter which at equal distances exert equal attractions on the same body, must be equal. But as it is not always possible to bring the attracting and attracted bodies to equal distances, their attractions at unequal distances may be observed, and the attractions which they would exert at equal distances may be thence inferred by the general law of gravitation, by which the attraction exerted by the same body increases as the square of the distance from it is diminished.

39. To solve this celebrated problem, it is necessary to bring the whole mass of the globe into direct comparison with some object whose mass is exactly known. This was accomplished first by Dr. Maskelyne, and afterwards by Cavendish. The former compared the attraction of the earth with that of a mountain in Perthshire, called Schehallion; the latter compared it with the attraction of a large ball of metal. Both obtained nearly the

same result, showing that the earth is a mass of matter about $5\frac{2}{3}$ heavier than an equal volume of water, or, what is the same, that the mean density of the earth is $5\frac{2}{3}$, or, more exactly, 5·67 times the density of water.

Among the substances which have nearly the same density as the earth may be mentioned, arsenic, chromium, chloride of silver, oxides of copper and zinc, and peroxide of iron.

40. The average weight of each cubic foot of the earth being 5·67 times the weight of a cubic foot of water, is 354·375 lbs., or 0·1587 of a ton. It follows, therefore, that the total weight of the earth is more than 6000,000000 billions of tons.

# TERRESTRIAL HEAT.

## CHAPTER I.

1. Heat an important agent.—2. Its local variations.—3. Diurnal period.—4. Annual period.—5. Mean diurnal temperature.—6. Mean monthly temperature.—7. Mean annual temperature.—8. Temperature of a place.—9. Isothermal lines.—10. Isothermal zones.—11. Thermal equator.—12. Second isothermal zone.—13. Third.—14. Fourth.—15. Fifth and Sixth.—16. Polar regions.—17. Climate varies on the same isothermal line.—18. Constant, variable, and extreme climates.—19. Classification of climates.—20. Extreme temperature in torrid and frigid zones.—21. Elevation affects temperature.—22. Snow line.—23. Thermal conditions below the surface.—24. Stratum of invariable temperature.—25. Varies with the latitude.—26. Its form.—27. Conditions above it.—28. Conditions below it.—29. Temperature of springs.—30. Temperature of greatest density of water.—31. Thermal condition of seas and

lakes.—32. Thermal condition of a frozen sea.—33. Process of thawing.—34. Depth of stratum of constant temperature. — 35. Superficial agitation extends only to a small depth.—36. Great utility of the state of maximum density.—37. Variations of temperature of the air.—38. Interchange of Equatorial and Polar waters—39. Polar ice.—40. Ice-fields.—41. Icebergs.—42. Their forms and magnitude.—43. Sunken icebergs.—44. Curious effects of their superficial fusion.—45. Depth of Polar Seas.—46. Cold of Polar regions.

1. Of all physical agents, heat is the most intimately connected with the terrestrial economy, the most important to the well-being of the organised tribes which inhabit the earth, and that upon the play of which the most remarkable revolutions which our planet has undergone have been more or less dependent. Since, in some future numbers of this series, we propose to explain these revolutions, and the traces they have left upon the crust of the globe, it will be useful to supply at present some preliminary information as to the laws which regulate the distribution of heat, and the periodical vicissitudes of temperature, on and below the surface of the earth, and in the superior strata of the atmosphere.

2. The superficial temperature of the earth varies with the latitude, gradually decreasing in proceeding from the equator towards the poles.

It also varies with the elevation of the point of observation, decreasing in proceeding to heights above the level of the sea, and varying according to certain conditions below that level, but in all cases increasing gradually for all depths below a certain stratum, at which the temperature is invariable.

At a given latitude and a given elevation the temperature varies with the character of the surface, according as the place of observation is on sea or land; and if on land, according to the nature, productions, or condition of the soil, and the accidents of the surface, such as its inclination or aspect.

3. At a given place the temperature undergoes two principal periodic variations, *diurnal* and *annual.*

The temperature falling to a minimum at a certain moment near sunrise, augments until it attains a maximum, at a certain moment after the sun has passed the meridian. The temperature then gradually falls until it returns to the minimum in the morning.

This diurnal thermometric period varies with the latitude, the elevation of the place, the character of the surface, and with a great variety of local conditions, which not only affect the hours of the maximum, minimum, and mean temperatures, but also the difference between the maximum and minimum, or the extent of the variation.

4. The annual thermometric period also varies with the latitude, and with all the other conditions that affect the thermal phenomena.

In order to be enabled to evolve the general thermal laws from phenomena so complicated and shifting, it is above all things necessary to define and ascertain those mean conditions or states, round which the thermometric oscillations take place.

5. The mean diurnal temperature is a temperature so taken between the extremes, that all those temperatures which are superior to it shall exceed it by exactly as much as those which are inferior to it shall fall short of it.

This mean temperature may always be obtained by taking the sum of the temperatures at sunrise, at 2 P.M., and at sunset, and dividing the result by 3, or more simply still, by adding together the maximum and minimum temperatures, and taking half their sum. Whichever of these methods be adopted, the same result very nearly will be obtained.

6. The mean temperature of the month is found by dividing the sum of the mean diurnal temperatures by the number of days.

7. The mean temperature of the year may be found by dividing the sum of the mean monthly temperatures by 12.

It is found that in each climate there is a certain month of which the mean temperature is identical with the mean temperature of the year, or very nearly so. This circumstance, when the month is known, supplies an easy method of observing the mean temperature of the year.

In our climate this month is October.

8. The mean annual temperature being observed in a given place for a series of years, the comparison of these means, one with another, will show whether the mean annual temperature is subject to variation, and if so, whether the variation is periodic or progressive. All observations hitherto made and recorded tend to support the conclusion, that the variations of the mean annual temperature are, like all other cosmical phenomena, periodic, and that the oscillations are made within definite limits and definite intervals.

But even though the period of these variations be not known, a near approximation to the mean temperature of the place may be obtained by adding together any attainable number of mean annual temperatures, and dividing their sum by their number. The probable accuracy of the result will be greater, the less the difference between the temperatures computed.

Thus it was found by a comparison of thirty mean annual temperatures at Paris, that the mean was 51°·44, and that the difference between the greatest and least of the mean annual temperatures was only 5°·4. It may therefore be assumed that

51°·44 does not differ by so much as two-tenths of a degree from the true mean temperature of that place.

Observation, however, has been hitherto so limited, both as to extent and duration, that this thermal character has been determined for a very limited number of places. Indications, nevertheless, have been obtained sufficiently clear and satisfactory to enable Humboldt to arrive at some general conclusions, which we shall now briefly state.

9. In proceeding successively along the same meridian from the equator towards the pole, the mean temperature decreases generally, but not regularly nor uniformly. At some points it even happens that the mean temperature augments, instead of decreasing. These irregularities are caused partly by the varying character of the surface, over which the meridian passes, and partly by the atmospheric effects produced by adjacent regions, and a multitude of other causes, local and accidental. As these causes of irregularity in the rate of decrease of the mean temperature, proceeding from the equator to the poles, are different upon different meridians, it is evident that the points of the meridians which surround the globe, at which the mean temperatures are equal, do not lie upon a parallel of latitude, as they would if the causes which affect the distribution of heat were free from all such irregularities and accidental influences.

If, then, a series of points be taken upon all the meridians surrounding the globe, having the same mean temperature, the line upon which such points are placed is called an *isothermal line.*

Each isothermal line is therefore characterised by the uniform mean temperature which prevails upon every part of it.

10. *Isothermal zones.*—The space included between two isothermal lines of given temperatures is called an *isothermal zone.*

The northern hemisphere has been distributed in relation to its thermal condition into six zones, limited by the six isothermal lines, characterised by the mean temperatures, 86°, 74°, 68°, 59°, 50°, 41°, and 32°.

The first zone is a space surrounding the globe, included between the equator and the isothermal line, whose temperature is 74°.

The mean temperature of the terrestrial equator is subject to very little variation, and it may therefore be considered as very nearly an isothermal line. Its mean temperature varies between the narrow limits of 81½° and 82½°.

11. If, upon each meridian, the point of greatest mean temperature be taken, the series of such points will follow a certain course round the globe, which has been designated as the *thermal equator.* This line departs from the terrestrial equator, to the extent of ten or twelve degrees on the north, and about eight degrees on the

south side, following a sinuous and irregular course, intersecting the terrestrial equator at about 100° and 160° east longitude.—It attains its greatest distances north at Jamaica, and at a point in Central Africa, having a latitude of 15°, and east longitude 10° or 12°. The greatest mean temperature of the thermal equator is 86°.

The isothermal line having the temperature of 74° is not very sinuous in its course, and does not much depart from the tropics.

12. The second zone, which is included between the isothermal parallels characterised by the mean temperatures of 74° and 68° is much more sinuous, and includes very various latitudes. At the points where it intersects the meridians of Europe, it is convex towards the north, and attains its greatest latitude in Algeria.

13. The third zone, included between the isothermal parallels which have the mean temperatures of 68° and 59°, passes over the coasts of France upon the Mediterranean, about the latitude 43°, and from thence bends southwards, both east and west, on the east towards Nangasaki and the coasts of Japan, and on the west to Natchez on the Mississippi.

14. The fourth zone is included between the parallels of mean temperatures 59° and 50°. It is convex to the north in Europe, including the chief part of France, and thence falls to the south on both sides, including Pekin on the east, and Philadelphia, New York, and Cincinnati on the west. It is evident from this arrangement of the fourth thermal zone, that the climate of Europe is warmer than that of those parts of the eastern and western continents which have the same latitude.

15. The fifth and sixth zones, included between the mean temperatures of 50° and 32°, are more sinuous, and include latitudes more various even than the preceding. The thermometric observations, however, which have been hitherto made in these regions, are too limited to supply ground for any general inferences respecting it.

16. The circle whose area is comprised within the isothermal parallel whose mean temperature is 32°, is still less known. Nevertheless, the results of the observations made by arctic voyagers within the last twenty years, afford ground for inferring that the mean temperature of the pole itself must be somewhere from 13° to 35° below the zero of Fahrenheit, or 45° to 67° below the temperature of melting ice.

17. When it is considered how different are the vegetable productions of places situate upon the same isothermal line, it will be evident that other thermal conditions besides the mean temperature must be ascertained before the climate of a place can be known. Thus London, New York, and Pekin are nearly on

the same isothermal line, yet their climates and vegetable productions are extremely different.

18. One of the circumstances which produce the most marked difference in the climates of places having the same mean temperature is the difference between the extreme temperatures. In this respect climates are classed as *constant*, *variable*, and *extreme*.

Constant climates are those in which the maximum and minimum monthly temperatures differ but little; variable climates are those in which the difference between these extremes is more considerable, and extreme climates are those in which this difference is very great.

Constant climates are sometimes called insular, because the effect of the ocean in equalising the temperature of the air is such as to give this character to the climates of islands.

19. *Examples of the classification of climates.*—The following examples will illustrate this classification of climates:—

| Places. | Mean Temp. | Highest Mean Monthly Temp. | Lowest Mean Monthly Temp. | Difference. |
|---|---|---|---|---|
| Funchal . . . . | 69° | 75°·56 | 62°·96 | 12°·60 |
| London . . . . . | 50·36 | 66·92 | 41·72 | 25·20 |
| Paris . . . . . | 51·08 | 65·30 | 36·14 | 29·16 |
| St. Malo . . . . | 54·14 | 64·40 | 37·76 | 26·64 |
| New York . . . . | 53·78 | 80·78 | 25·34 | 55·44 |
| Pekin . . . . . | 53·86 | 84·38 | 24·62 | 59·76 |

Funchal offers the example of a constant or insular climate; London, Paris, and St. Malo, of a variable; and New York and Pekin of an extreme climate.

20. The highest temperature of the air which has been observed within the torrid zone is 130°, which was observed by MM. Lyon and Ritchie, in the Oasis of Mourzouk. This, however, is an extreme and exceptional case, the temperature even in this zone, rarely exceeding 120°.

The lowest temperatures observed by arctic voyagers in the polar regions range from 40° to 60° below zero of Fahrenheit, which is from 70° to 90° below the temperature of melting ice. Thus it appears that the air at the surface of the earth ranges between — 60° and + 120°, the extremes differing by 180°.

21. Innumerable phenomena show that the temperature of the air falls as the elevation increases. The presence of eternal snow

on the elevated parts of mountain ranges, in every part of the globe, not excepting even the torrid zone, is a striking evidence of this.

It appears, from observations made upon the declivities of the vast mountain ranges which traverse the equatorial regions, that the decrease of temperature is neither uniform nor regular.

The observations made in temperate climates give results equally irregular. Gay-Lussac found ascending in a balloon, that the thermometric column fell one degree for an elevation of about 320 feet. On the Alps the height which produces a fall of one degree is from 260 to 280 feet, and on the Pyrenees from 220 to 430 feet. It may be assumed, that in the tropical regions, an elevation of 300 feet, and in our latitudes from 300 to 330 feet, corresponds to a fall of one degree of temperature on an average, subject, however, to considerable local variation.

22. It might appear that in those elevations at which the temperature falls to 32°, water cannot exist in the liquid state, and we might expect that above this limit we should find the surface invested with perpetual snow. Observation nevertheless shows such an inference to be erroneous. Humboldt in the equatorial regions, and M. Leopold de Buch in Norway and Lapland, have shown that the SNOW-LINE does not correspond with a mean temperature of 32° for the superficial atmosphere, but that on the contrary, within the tropics, it is marked by a mean temperature of about 35°, while in the northern regions, in latitudes of from 60° to 70°, the mean temperature is $26\frac{1}{2}$°.

It appears that the snow-line is determined not so much by the mean annual temperature of the air as by the temperature of the hottest month. The higher this temperature is, the more elevated will be the limit of perpetual snow. But the temperature of the hottest month depends on a great variety of local conditions, such as the cloudy state of the atmosphere, the nature of the soil, the inclination and aspect of the surface, the prevailing winds, &c.

23. At a given place the surface of the ground undergoes a periodical variation of temperature, attaining a certain maximum in summer and a minimum in winter, and gradually, but not regularly or uniformly, augmenting from the minimum to the maximum, and decreasing from the maximum to the minimum.

The question then arises as to whether this periodic variation of temperature is propagated downwards through the crust of the earth, and if so, whether in its descent it undergoes any and what modifications?

To explain the phenomena which have been ascertained by observation, let us express the mean temperature by M, and let the maximum and minimum temperatures be T and *t*.

If we penetrate to depths more or less considerable, we shall find that the mean temperature M of the strata will be very nearly the same as at the surface. The extreme temperatures T and $t$, will, however, undergo a considerable change, T decreasing, and $t$ increasing. Thus the extremes gradually approach each other as the depth increases, the mean M remaining nearly unaltered.

24. A certain depth will therefore be attained at length, when the maximum temperature T, by its continual decrease, and the minimum temperature $t$, by its continual increase, will become respectively equal to the mean temperature M. At this depth, therefore, the periodical variations at the surface disappear; and the mean temperature M is maintained permanently without the least change.

This mean temperature, however, though nearly, is not precisely equal to the mean temperature at the surface. In descending, M undergoes a slight increase, and at the depth where T and $t$ become equal to M, and the variation disappears, the mean temperature is a little higher than the mean temperature of the surface.

25. The depth at which the superficial vicissitudes of temperature disappear varies with the latitude, with the nature of the surface, and other circumstances. In our climates it varies from 80 to 100 feet. It diminishes in proceeding towards the equator, and increases towards the pole. The excess of the permanent temperature at this depth above the mean temperature at the surface, increases with the latitude.

The same thermometer which has been kept for sixty years in the vaults of the Observatory at Paris, at the depth of eighty-eight feet below the surface, has shown, during that interval, the temperature of 11°·82 cent., which is equal to 53¼° Fahr., without varying more than half a degree of Fahr., and even this variation, small as it is, has been explained by the effects of currents of air produced by the quarrying operations in the neighbourhood of the Observatory.

26. We must therefore infer, that within the surface of the earth there exists a stratum of which the temperature is invariable, and so placed that all strata superior to it are more or less affected by the thermal vicissitudes of the surface, more so the nearer they are to the surface, and that this stratum of invariable temperature has an irregular form, approaching nearer to the surface at some places, and receding further from it at others, the nature and character of the surface, mountains, valleys, and plains, seas, lakes, and rivers, the greater or less distance from the equator or poles, and a thousand other circumstances, imparting to it variations of form, which it will require observations and experiments

much more long-continued and extensive than have hitherto been made, to render manifest.

27. The thermometric observations on the periodical changes which take place above the stratum of invariable temperature are not so numerous as could be desired; nevertheless, the following general conditions have been ascertained, especially in the middle latitudes of the northern hemisphere:—

1. The diurnal variations of temperature are not sensible to a greater depth than $3\frac{1}{2}$ feet.

2. The difference between the extreme temperatures of the strata decreases in geometrical progression for depths measured in arithmetical progression, or nearly so.

Thus, at the depth of twenty-five feet the difference between the extreme temperatures $T$ and $t$, is reduced to two degrees; at fifty feet it is diminished to the fifth of a degree, and at sixty or eighty feet to the fiftieth of a degree.

3. Since the effects of the superficial variation must require a certain time to penetrate the strata, it is evident that the epoch at which each stratum attains its maximum and minimum temperatures will be different from those at which the other strata and the surface attain them. The lower the strata the greater will be the difference between the times of attaining those limits as compared with the surface.

28. The same uniformity of temperature which prevails in the invariable stratum is also observed at all greater depths; but the temperature increases with the depth. Thus, each successive stratum, in descending, has a characteristic temperature, which never changes. The rate at which this temperature augments with the depth below the invariable stratum is extremely different in different localities. In some there is an increase of one degree for every thirty feet, while in others the same increase corresponds to a depth of 100 feet. It may be assumed, in general, that an increase of one degree of temperature will take place for every fifty or sixty feet of depth.

29. The permanency of the temperatures of the inferior strata is rendered manifest by the uniformity of the temperature of springs, of which the water rises from any considerable depths. At all seasons of the year the water of such springs maintains the same uniform temperature.

It may be assumed that the temperature of the water proceeding from such springs is that of the strata from which they rise. In these latitudes it is found in general to be a little above the mean temperature of the air for ordinary springs, that is from those which probably rise from strata not below the invariable stratum. In higher latitudes the excess of temperature is greater, a fact which is in accordance with what has been already explained.

It has not been certainly ascertained whether the hot springs, some of which rise to a temperature little less than that of boiling water, derive their heat from the great depth of the strata from which they rise, or from local conditions affecting the strata. The uniformity of the temperature of many of them appears to favour the former hypothesis; but it must not be forgotten that other geological conditions besides mere depth may operate with the same permanency and regularity.

30. It is well known that bodies in general expand when they are heated, and contract when they are cooled. Water, when its temperature falls below 40°, presents a most remarkable exception to this general law. It continues in accordance with the law to contract, though in a continually diminished degree, from 40° to 38°·8, and when it arrives at the latter temperature the contraction ceases altogether. When its temperature falls below 38°·8, instead of contracting, it *expands*, and it continues to expand until it is frozen, which takes place at 32°.

It follows from this that the density of water, or its weight bulk for bulk compared with itself at different temperatures is greatest when it has the temperature of 38°·8, which is therefore called the temperature of greatest density.*

31. This anomalous quality of water when its temperature falls below 38°·8 Fahr. and its consequent maximum density at that temperature, is attended with most remarkable and important consequences in the phenomena of the waters of the globe, and in the economy of the tribes of organised creatures which inhabit them. It is easy to show that, but for this provision, exceptional as it seems, disturbances would take place, and changes ensue, which would be attended with effects of the most injurious description in the economy of nature.

If a large collection of water, such as an ocean, a sea, or a lake, be exposed to continued cold, so that its superficial stratum shall have its temperature constantly reduced, the following effects will be manifested.

The superficial stratum falling in temperature, will become heavier, volume for volume, than the strata below it, and will therefore sink, the inferior strata rising and taking its place. These in their turn being cooled will sink, and in this manner a continual system of downward and upward currents will be maintained, by means of which the temperature of the entire mass of liquid will be continually equalised and rendered uniform from

* See Tract on Water (5).

the surface to the bottom. This will continue so long as the superficial stratum is rendered heavier, volume for volume, than those below it, by being lowered in temperature. But the superficial stratum, and all the inferior strata, will at length be reduced to the uniform temperature of 38°·8. After this the system of currents upwards and downwards will cease. The several strata will assume a state of repose. When the superficial stratum is reduced to a temperature lower than 38°·8 (which is that of the maximum density of water), it will become lighter, volume for volume, instead of being heavier than the inferior strata. It will therefore float upon them. The stratum immediately below it, and in contact with it, will be reduced in temperature, but in a less degree; and in like manner a succession of strata, one below the other, to a certain depth, will be lowered in temperature by the cold of those above them, but each stratum being lighter than those below, will remain at rest, and no interchange by currents will take place between stratum and stratum. If water were a good conductor of heat, the cooling effect of the surface would extend downwards to a considerable depth. But water being, on the contrary, an extremely imperfect conductor, the effect of the superficial temperature will extend only to a very limited depth; and at and below that limit, the uniform temperature of 38°·8, that of the greatest density, will be maintained.

This state of repose will continue until the superficial stratum falls to 32° *, after which it will be congealed. When its surface is solidified, if it be still exposed to a cold lower than 32°, the temperature of the surface of the ice will continue to fall, and this reduced temperature will be propagated downward, diminishing, however, in degree, so as to reduce the temperature of the stratum on which the ice rests to 32°, and therefore to continue the process of congelation, and to thicken the ice.

If ice were a good conductor of heat, this downward process of congelation would be continued indefinitely, and it would not be impossible that the entire mass of water from the surface to the bottom, whatever be the depth, might be solidified. Ice, however, is nearly as bad a conductor of heat as water, so that the superficial temperature can be propagated only to a very inconsiderable depth; and it is found accordingly, that the crust of ice formed even on the surface of the polar seas, does not exceed the average thickness of twenty feet.

32. The thermal condition, therefore, of a frozen sea, is a state of molecular repose, as absolute as if the whole mass of liquid were solid. The temperature at the surface of the ice being below the

* For sea water the freezing point is 28½°.

freezing point, increases in descending until it rises to the freezing point, at the stratum where the ice ceases, and the liquid water commences. Below this the temperature still augments until it reaches 38°·8, the temperature of maximum density of water, and this temperature is continued uniform to the bottom.

33. Let us now consider what effects will be produced, if the superficial strata be exposed to an increase of temperature. After the fusion of the ice, the temperature of the surface will gradually rise from 32° to 38°·8, the temperature of greatest density. When the superficial stratum rises above 32°, it will become heavier than the stratum under it, and an interchange by currents, and a consequent equalisation of temperature, will take place, and this will continue until the superficial stratum attain the temperature of 38°·8, when the temperature of the whole mass of water from the surface to the bottom will become uniform.

After this a further elevation of the temperature of the superficial stratum will render it lighter than those below it, and no currents will be produced, the liquid remaining at rest; and this state of repose will continue so long as the temperature continues to rise.

Every fall of the superficial temperature, so long as it continues above 38°·8, will be attended with an interchange of currents between the superficial and those inferior strata whose temperature is above 38°·8, and a consequent equalisation of temperature.

34. It appears, therefore, to result as a necessary consequence from what has been explained, and this inference is fully confirmed by experiment and observations, that there exists in oceans, seas, and other large and deep collections of water, a certain stratum, which retains permanently, and without the slightest variation, the temperature of 38°·8, which characterises the state of greatest density, and that all the inferior strata equally share this temperature. At the lower latitudes, the superior strata have a higher, at the higher latitudes a lower temperature, and at a certain mean latitude the stratum of invariable temperature coincides with the surface.

In accordance with this, it has been found by observation that in the torrid zone, where the superficial temperature of the sea is about 83°, the temperature decreases with the depth until we attain the stratum of invariable temperature, the depth of which, upon the Line, is estimated at about 7000 feet. The depth of this stratum gradually diminishes as the latitude increases, and the limit at which it coincides with the surface is somewhere between 55° and 60°. Above this the temperature of the sea increases as the depth of the stratum increases, until we sink to the stratum of invariable temperature, the depth of which at the highest latitudes at which observations have been made, is estimated at about 4500 feet.

35. It might be imagined that the temperature of the surface would be propagated downwards, and that a thermal equalisation might therefore be produced by the intermixture of the superior with the inferior strata, arising from the agitation of the surface of the waters by atmospheric commotions. It is found, however, that these effects, even in the case of the most violent storms and hurricanes, extend to no great depth, and that while the surface of the ocean is furrowed by waves of the greatest height and extent, the inferior strata are in the most absolute repose.

36. If water followed the general law, in virtue of which all bodies become more dense as their temperature is lowered, a continued frost might congeal the ocean from its surface to the bottom, and certainly would do so in the polar regions; for in that case the system of vertical currents, passing upwards and downwards, and producing an equalisation of temperature, which has been shown to prevail above 38°·8, would equally prevail below that point, and consequently the same equalisation of temperature would be continued, until the entire mass of water, from the surface to the bottom, would be reduced to the point of congelation, and would consequently be converted into a solid mass, all the organised tribes inhabiting the waters being destroyed.

The existence of a temperature of maximum density at a point of the thermometric scale above the point of congelation of water, combined with the very feeble conducting power of water, whether in the liquid or solid state, renders such a catastrophe impossible.

37. The air is subject to less extreme changes of temperature at sea than on land. Thus, in the torrid zone, while the temperature on land suffers a diurnal variation amounting to 10°, the extreme diurnal variation at sea does not exceed 3½°. In the temperate zone the diurnal variation at sea is limited generally to about 5½°, while on continents it is very various and everywhere considerable. In different parts of Europe it varies from 20° to 25°.

At sea as on land the time of lowest temperature is that of sunrise, but the time of greatest heat is about noon, while on land it is at two or three hours after noon.

On comparing the temperature of the air at sea with the superficial temperature of the water, it has been found that between the tropics the air, when at its highest temperature, is warmer than the water, but that its mean diurnal temperature is lower than that of the water.

In latitudes between 25° and 50° the temperature of the air is very rarely higher than that of the water, and in the polar regions the air is never found as warm as the surface of the water. It is, on the contrary, in general at a very much lower temperature.

38. Much uncertainty prevails as to the thermal phenomena manifested in the vast collections of water which cover the greater part of the surface of the globe. It appears, however, to be admitted that the currents caused by the difference of the pressures of strata at the same level in the polar and equatorial seas, produce an interchange of waters, which contributes in a great degree to moderate the extreme thermal effects of these regions, the current from the pole reducing the temperature of the equatorial waters, and that from the line raising the temperature of the polar waters and contributing to the fusion of the ice. A superficial current directed from the line towards the poles carries to the colder regions the heated waters of the tropics, while a counter current in the inferior strata carries from the poles towards the line the colder waters. Although the prevalence of these currents may be regarded as established, they are nevertheless modified, both in their intensity and direction, by a multitude of causes connected with the depth and form of the bottom, and the local influence of winds and tides.

39. The stupendous mass of water in the solid state which forms an eternal crust encasing the regions of the globe immediately around the poles, presents one of the grandest and most imposing classes of natural phenomena. The observations and researches of Captain Scoresby have supplied a great mass of valuable information in this department of physical geography.

40. Upon the coasts of Spitzbergen and Greenland vast fields of ice are found, the extent of which amounts to not less than twelve to fifteen hundred square miles, the thickness varying from twenty to twenty-five feet. The surface is sometimes so even that a sledge can run without difficulty for an hundred miles in the same direction. It is, however, in some places, on the contrary, as uneven as the surface of land, the masses of ice collecting in columns and eminences of a variety of forms, rising to heights of from twenty to thirty feet, and presenting the most striking and picturesque appearances. These prodigious crystals sometimes exhibit gorgeous tints of greenish blue, resembling certain varieties of topaz, and sometimes this is varied by a thick covering of snow upon their summits, which gives them the appearance of cliffs of chalk or white marble, marked by an endless variety of form and outline.

41. These vast ice-fields are sometimes suddenly broken, by the pressure of the subjacent waters, into fragments presenting a

surface of from 100 to 200 hundred square yards. These being dispersed, are carried in various directions by currents, and sometimes by the effect of intersecting currents they are brought into collision with a fearful crash. A ship, which might chance in such a case to be found between them could no more resist their force than could a glass vessel the effect of a cannon ball. Terrible disasters occur from time to time from this cause. It is by the effects of these currents upon the floating masses of broken ice that these seas are opened to the polar navigators. It is thus that whalers are enabled to reach the parallels from 70° to 80°, which are the favourite resort of those monsters of the deep which they pursue.

42. Sometimes after such collisions new icebergs arise from the fragments which are heaped one upon another, "Pelion on Ossa," more stupendous still than those which have been broken. In such cases the masses which result assume forms infinitely various, rising often to an elevation of thirty to fifty feet above the surface of the water; and since the weight of ice is about four-fifths of the weight of its own bulk of water, it follows that the magnitude of these masses submerged is four times as great as that which is above the surface. The total height of these floating icebergs, therefore, including the part submerged, must be from 150 to 250 feet.

43. It happens sometimes that two such icebergs resting on the extremities of a fragment of ice 100 or 120 feet in length, keep it sunk at a certain depth below the surface of the water. A vessel in such cases may sail between the icebergs and over the sunken ice; but such a course is attended with the greatest danger, for if any accidental cause should detach either of the icebergs which keep down the intermediate mass while the ship is passing, the latter by its buoyancy will rise above the surface, and will throw up the ship with irresistible force.

44. Icebergs are observed in Baffin's Bay of much greater magnitude than off the coast of Greenland. They rise there frequently to the height of 100 to 130 feet above the surface, and their total height, including the part immersed, must therefore amount to 500 or 650 feet. These masses appear generally of a beautiful blue colour, and having all the transparency of crystals. During the summer months, when the sun in these high latitudes never sets, a superficial fusion is produced, which causes immense cascades, which, descending from their summit and increasing in volume as they descend, are precipitated into the sea in parabolic curves. Sometimes, on the approach of the cold season, these liquid arches are seized and solidified by the intensity of the cold without losing their form, and seem as if caught in their flight between the brink from which they were projected and the surface,

and suddenly congealed. These stupendous arches, however, do not always possess cohesion in proportion to their weight, and after augmenting in volume to a certain limit, sink under their weight, and, breaking with a terrific crash, fall into the sea.

45. The depth of the seas off the coast of Greenland is not considerable. Whales, being harpooned, often plunge in their agony to the bottom, carrying with them the harpoon and line attached to it. When they float they bear upon their bodies evidence of having reached the bottom by the impression they retain of it, and the length of line they carry with them in such cases shows that depth does not exceed 3000 or 4000 feet. About the middle of the space between Spitzbergen and Greenland the soundings have reached 8000 feet without finding bottom.

46. The degree of cold of the polar regions, like the temperature of all other parts of the globe, depends on the extent and depth of the seas. If there be extensive tracts of surface not covered by water, or covered only by a small depth, the influence of the water in moderating and equalising the temperature is greatly diminished. Hence it is that the temperature of the south polar regions is more moderate than that of the north. After passing the latitude of the New Orcades and the New Shetlands, which form a barrier of ice, the navigator enters an open sea, which, according to all appearance, extends to the pole. Much, however, still remains to be discovered respecting the physical condition of these regions.

# TERRESTRIAL HEAT.

## CHAPTER II.

47. Sources of external heat.—48. Solar heat.—49. Its quantity ascertained.—50. Heat at sun's surface.—51. Temperature of celestial spaces.—52. Quantity of heat supplied by them.—53. Summary of heat supplied.—54. Winds.—55. Produced by rarefaction and compression.—56. Sudden condensation of vapour.—57. Hurricanes.—58. Their cause.—59. Waterspouts.—60. Evaporation.—61. Saturation of air.—62. May arise from intermixing strata.—63. Effect of pressure.—64. Dew.—65. Hoar frost.—66. Artificial ice.—67. Fogs and clouds.—68. Rain.—69. Its quantity.—70. Snow.—71. Hail.—72. Hailstones.—73. Extraordinary hailstones.

47. Whatever may be the sources of internal heat, the globe of the earth would, after a certain time, be reduced to a state of absolute cold, if it did not receive from external sources the quantity of heat necessary to repair its losses. If the globe were

suspended in space, all other bodies from which heat could be supplied to it being removed, the heat which now pervades the earth and its surrounding atmosphere would be necessarily dissipated by radiation, and would thus escape into the infinite depths of space. The temperature of the atmosphere, and those of the successive strata, extending from the surface to the centre of the globe, would thus be continually and indefinitely diminished.

As no such fall of temperature takes place, and as, on the contrary, the mean temperature of the globe is maintained at an invariable standard, the variations incidental to season and climate being all periodical, and producing in their ultimate result a mutual compensation, it remains to be shown from what sources the heat is derived which maintains the mean temperature of the globe at this invariable standard, notwithstanding the large amount of heat which it loses by radiation into the surrounding space.

All the bodies of the material universe, which are distributed in countless numbers throughout the infinitude of space, are sources of heat, and centres from which that physical agent is radiated in all directions. The effect produced by the radiation of each of these diminishes in the same proportion as the square of its distance increases. The fixed stars are bodies analogous to our sun, and at distances so enormous that the effect of the radiation of any individual star is altogether insensible. When, however, it is considered that the multitude of these stars spread over the firmament is so prodigious that in some places many thousand are crowded together within a space no greater than that occupied by the disc of the full moon, it will not be matter of surprise that the feebleness of thermal influence, due to their immense distances, is compensated to a great extent by their countless number; and that, consequently, their calorific effects in those regions of space through which the earth passes in its annual course is, as will presently appear, not only far from being insensible, but is very little inferior to the calorific power of the sun itself.

We are, then, to consider the waste of heat which the earth suffers by radiation as repaired by the heat which it receives from two sources, the sun and the stellar universe; and it remains to explain what is the actual quantity of heat thus supplied to the earth, and what proportion of it is due to each of these causes.

48. An elaborate series of experiments were made by M. Pouillet, and concluded in 1838, with the view of obtaining, by means independent of all hypothesis as to the physical character of the sun, an estimate of the actual calorific power of that luminary. A detailed report of these observations and experiments, and an

elaborate analysis of the results derived from them, appeared in the Transactions of the Academy of Sciences of Paris for that year.

It would be incompatible with the elementary nature and the consequent limits of this work, to enter into the details of these researches. We shall, therefore, confine ourselves here briefly to state their results.

When the firmament is quite unclouded, the atmosphere absorbs about one-fourth of the heat of those solar rays which enter it vertically. A greater absorption takes place for rays which enter it obliquely, and the absorption is augmented in a certain ascertained proportion, with the increase of obliquity. It results from the analysis of the results obtained in the researches of M. Pouillet, that about forty per cent. of all the heat transmitted by the sun to the earth is absorbed by the atmosphere, and that consequently only sixty per cent. of this heat reaches the surface. It must, however, be observed that a part of the radiant heat, intercepted by the atmosphere, raising the temperature of the air, is afterwards transmitted, as well by radiation as by contact, from the atmosphere to the earth.

By means of direct observation and experiment made with instruments contrived by him, called *pyrheliometers*, by means of which the heat of the solar radiation was made to affect a known weight of water at a known temperature, M. Pouillet ascertained the actual quantity of heat which the solar rays would impart per minute to a surface of a given magnitude, on which they would fall vertically. This being determined, it was easy to calculate the quantity of heat imparted by the sun in a minute to the hemisphere of the earth which is presented to it, for that quantity is the same which would be imparted to the surface of the great circle which forms the base of that hemisphere, if the solar rays were incident perpendicularly upon it.

49. In this manner it was ascertained, that if the total quantity of heat which the earth receives from the sun in a year were uniformly diffused over all parts of the surface, and were completely absorbed in the fusion of a shell of ice encrusting the globe, it would be sufficient to liquefy a depth of 100 feet of such shell.

Since a cubic foot of ice weighs 54 lb., it follows that the average annual supply of heat received from the sun per square foot of the earth's surface would be sufficient to dissolve 5400 lb. weight of ice.

This fact being ascertained supplies the means of calculating the quantity of heat emitted from the surface of the sun, independently of any hypothesis respecting its physical constitution.

It is evident from the uniform calorific effects produced by the solar rays at the earth, while the sun revolves on its axis exposing successively every side to the earth in the course of about twenty-five days, that the calorific emanation from all parts of the solar surface is the same. Assuming this, then, it will follow, that the heat which the surface of a sphere surrounding the sun at the distance of the earth would receive would be so many times more than the heat received by the earth as the entire surface of such sphere would be greater than that part of it which the earth would occupy. The calculation of this is a simple problem of elementary geometry.

But such a spherical surface surrounding the sun and concentrical with it, would necessarily receive all the heat radiated by that luminary, and the result of the calculation proves that the quantity of heat emitted by the sun per minute is such as would suffice to dissolve a shell of ice enveloping the sun, and having a thickness of $38\frac{6}{10}$ feet; and that the heat emitted per day would dissolve such a shell, having a thickness of 55,748 feet, or about $10\frac{1}{2}$ miles.

50. The most powerful blast furnaces do not emit for a given extent of fire surface more than the seventh part of this quantity of heat. It must therefore be inferred that each square foot of the surface of the sun emits about seven times as much heat as is issued by a square foot of the fire surface of the fiercest blast furnace.

51. When the surface of the earth during the night is exposed to an unclouded sky, an interchange of heat takes place by radiation. It radiates a certain part of the heat which pervades it, and it receives, on the other hand, the heat radiated from two sources,—1st, from the strata of atmosphere, extending from the surface of the earth to the summit of the atmospheric column; and 2nd, from the celestial spaces, which lie outside this limit, and which receive their heat from the radiation of the countless numbers of suns which compose the stellar universe. M. Pouillet, by a series of ingeniously contrived experiments and observations, made with the aid of an apparatus contrived by him, called an *actinometer*, has been enabled to obtain an approximate estimate of the proportion of the heat received by the earth which is due to each of these two sources, and thereby to determine the actual temperature of the region of space through which the earth and planets move. The objects and limits of this work do not permit us to give the details of these researches, and we must therefore confine ourselves here to the statement of their results.

It appears from the observations, that the actual temperature of space is included between the minor limit of 315° and the major limit of 207° below the temperature of melting ice, or between

—283° and —175° Fahr. At what point between these limits the real temperature lies, is not yet satisfactorily ascertained, but M. Pouillet thinks that it cannot differ much from —224° Fahr.

52. It is proved from these results, that the quantity of heat imparted to the earth in a year, by the radiation of the celestial space, is such as would liquefy a spherical shell of ice, covering the entire surface of the earth, the thickness of which would be 85 feet, and that forty per cent. of this quantity is absorbed by the atmosphere.

Thus the total quantity of heat received annually by the earth is such as would liquefy a spherical shell of ice 185 feet thick, of which 100 feet are due to the sun, and 85 feet to the heat which emanates from the stellar universe.

The fact that the celestial spaces supply very little less heat to the earth annually than the sun, may appear strange, when the very low temperature of these spaces is considered, a temperature 180° lower than the cold of the pole during the presence of the sun. It must, however, be remembered that while the space from which the solar radiation emanates, is only that part of the firmament occupied by the disc of the sun, that from which the celestial radiation proceeds is the entire celestial sphere, the area of which is about five million times greater than the solar disc. It will therefore cease to create surprise, that the collective effect of an area so extensive should be little short of that of the sun.

The calorific effect due to the solar radiation, according to the calculations and observations of M. Pouillet, exceeds that which resulted from the formulæ of Poisson. These formulæ were obtained from the consideration of the variation of the temperature of the strata of the earth at different depths below the surface. M. Pouillet thinks that the results proceeding from the two methods would be brought into accordance if the influence of the atmosphere on solar heat, which, as appears from what has been explained, is very considerable, could be introduced in a more direct manner into Poisson's formulæ.

53. In fine, therefore, the researches of M. Pouillet give the following results, which must be received as mere approximations subject to correction by future observation:

1st. That the sun supplies the earth annually with as much heat as would liquefy 100 feet thick of ice covering the entire globe.

2nd. That the celestial spaces supply as much as would liquefy 85 feet thick.

3rd. That forty per cent of the one and the other supply is absorbed by the atmosphere, and sixty per cent received by the earth.

4th. That of the heat radiated by the earth, ninety per cent. is intercepted by the atmosphere, and ten per cent. dispersed in space.

5th. That the heat evolved on the surface of the sun in a day would liquefy a shell of ice 10½ miles thick, enveloping the sun, and the intensity of the solar fire is seven times greater than that of the fiercest blast furnace.

6th. That the temperature of space outside the atmosphere of the earth is 256° below that of melting ice.

7th. That the solar heat alone, constitutes only two-thirds of the entire quantity of heat supplied to the earth to repair its thermal losses by terrestrial radiation; and that without the heat supplied by stellar radiation, the temperature of the earth would fall to a point which would be incompatible with organic life.

54. No meteorological phenomenon has had so many observers, and there is none of which the theory is so little understood, as the winds. The art of navigation has produced in every seaman an observer, profoundly interested in the discovery of the laws which govern a class of phenomena, upon the knowledge of which depends not only his professional success but his personal security, and the lives and property committed to his charge.

The chief part of the knowledge which has been collected respecting the causes which produce these atmospheric currents is derived, nevertheless, much more from the comparison of the registers of observatories than from the practical experience of mariners.

55. Winds are propagated either by *compression* or by *rarefaction*. In the former case they are developed in the same direction in which they blow; in the latter case they are developed in the contrary direction. To render this intelligible, let us imagine a column of air included in a tube. If a piston inserted in one end of the tube be driven from the mouth inwards, the air contiguous to it will be compressed, and this portion of air will compress the succeeding portion, and so on; the compression being propagated from the end at which the piston enters toward the opposite end. The remote end being open, the air will flow in a current driven before the piston in the same direction in which the compression is propagated.

If we imagine, on the other hand, a piston inserted in the tube at some distance from its mouth, to be drawn outwards toward the mouth, the air behind it will expand into the space deserted by the piston, and a momentary rarefaction will be produced. The next portion of air will in like manner follow that which is next the piston, the rarefaction which begins at the piston being propagated backwards through the tube in a direction contrary to the motion of the piston and that of the current of air which follows it.

What is here supposed to take place in the tube is exhibited on a larger scale in the atmosphere. Any physical cause which produces a compression of the atmosphere from north to south will produce a north wind; and any cause which produces a rarefaction from north to south will produce a south wind.

56. Of all the causes by which winds are produced, the most frequent is the sudden condensation of vapour suspended in the atmosphere. In general the atmosphere above us consists of a mixture of air properly so called, and water, either in the state of vapour, or in a vesicular state, the nature and origin of which has not yet been clearly ascertained. In either case its sudden conversion into the liquid state, and its consequent precipitation to the earth, leaves the space it occupied in the atmosphere a vacuum, and a corresponding rarefaction of the air previously mixed with the vapour ensues. The adjacent strata immediately rush in to re-establish the equilibrium of pneumatic pressure, and winds are consequently produced.

The propagation of winds by rarefaction manifested in directions contrary to that of the winds themselves, is common in the North of Europe. Wargentin gives various examples of this. When a west wind springs up, it is felt, he observes, at Moscow before it reaches Abo, although the latter city is four hundred leagues west of Moscow, and it does not reach Sweden until after it has passed over Finland.

57. The intertropical regions are the theatre of hurricanes. It is there only that these atmospheric commotions are displayed in all their terrors. In the temperate zones tempests are not only more rare in their occurrence but much less violent in their force. In the circumpolar zone the winds seldom acquire the force which would justify the title of a storm.

The hurricanes of the warm climates spread over a considerable width, and extend through a still more considerable length. Some are recorded which have swept over a distance of four or five hundred leagues with a nearly uniform violence.

It is only by recounting the effects produced by these vast commotions of the atmospheric ocean, that any estimate can be formed of the force which air, attenuated and light as that fluid is, may acquire when a great velocity is given to it. In hurricanes such as that which took place at Guadaloupe on the 25th July, 1825, houses the most solidly constructed were overthrown. A new building erected in the most durable manner by the government was razed to the ground. Tiles carried from the roof were projected against thick doors with such force as to pass through them like a cannon ball. A plank of wood $3\frac{1}{2}$ feet long, 9 inches wide, and an inch thick, was projected with such force as to cut through a branch of palm wood 18 inches in diameter. A piece of wood 15 feet long and 8 inches square in its cross section, was projected upon a hard paved road, and buried to a depth of more than three feet in it. A strong iron gate in front of the governor's house was carried away, and three twenty-four pounders erected on the fort were dismounted.

58. These effects, prodigious as they are, all arise from mechanical causes. There is no agent engaged in hurricanes more subtle than the mechanical force of air in motion, and since the weight and density of the air suffer no important change, the vast momentum manifested by such effects as those described above, must be ascribed altogether to the extraordinary velocity imparted to the air by the magnitude of the local vacuum produced, as already stated, by the sudden condensation of vapour. To form some approximate estimate of this it may be observed that, in the intertropical regions, a fall of rain often takes place over a vast extent of surface, sufficient in quantity to cover it with a stratum of water more than an inch in depth. If such a fall of rain were to take place over the extent of a hundred square leagues, as sometimes happens, the vapour from which such a quantity of liquid would be produced by condensation would, at the temperature of only 50°, occupy a volume of 100000 times greater than that of the liquid: and, consequently, in the atmosphere over the surface of 100 square leagues it would fill a space 9000 feet, or nearly two miles in height. The extent of the vacuum produced by its condensation would be a volume nearly equal to 200 cubic miles, or to the volume of a column whose base is a square mile and whose height is 200 miles.

59. The phenomena, called water or land spouts according as they are manifested at sea or on land, consist apparently of dense masses of aqueous vapour and air, having at once a gyratory and progressive motion, and resembling in form a conical cloud, the base of which is presented upwards, and the vertex of which generally rests upon the ground, but sometimes assumes a contrary position. This phenomenon is attended with a sound like that of a waggon rolling on a rough pavement.

Violent mechanical effects sometimes attend these meteors. Large trees torn up by the roots, stripped of their leaves, and exhibiting all the appearances of having been struck by lightning, are projected to great distances. Houses are often thrown down, unroofed, and otherwise injured or destroyed, when they lie in the course of these meteors. Rain, hail, and frequently globes of fire, like the ball lightning, also accompany them.

The various appearances exhibited by water-spouts are represented in fig. 1.

No satisfactory theory has yet connected these phenomena with the general laws of physics.

60. If the surface of a sea, lake, or other large collection of water were exposed to the atmosphere consisting of pure air without any admixture of vapour, evaporation would immediately commence, and the vapour developed at the surface of the water would ascend into and mix with the atmosphere. The pressure of the atmosphere would then be the sum of the pressures of the atmosphere, properly so called, and of the vapour suspended in it, since neither of these elastic fluids can augment or diminish the pressure of the other.

Fig. 1.

The vapour developed from the surface of the water thus mingling with the atmosphere, acquires a common temperature with it. This vapour, therefore, receiving thus from the air with which it is intermixed more or less heat, after having passed into the vaporous state, is *superheated vapour*. It has, therefore, a greater temperature than that which corresponds to its density, or, what is the same, it has a less density than that which corresponds to its temperature. Such vapour may therefore lose temperature to a certain extent without being condensed.

61. But if the same atmosphere continue to be suspended over the surface of water, the process of evaporation being continued, the quantity of vapour which rises into the air and mingles with it will be continually increased until it acquires the greatest density which is compatible with its temperature. Evaporation must then cease, and the air is said to be *saturated* with vapour.

If the temperature of the air in such case rise, evaporation will recommence and will continue until the vapour shall acquire the greatest density compatible with the increased temperature, and will then cease, the air being, as before, *saturated*.

But if the temperature fall, the greatest density of vapour compatible with it being less than at the higher temperature, a part of the vapour must be condensed, and this condensation must continue until the vapour suspended in the air shall be reduced to that state of density which is the greatest compatible with the reduced temperature.

A fluid so light and mobile as the atmosphere, can never remain long in a state of repose, and the column of air suspended over the surface of any collection of water however extensive, is subject to frequent change. In general, therefore, before any such portion of the atmosphere becomes saturated by evaporation, it is removed and replaced by another portion. It happens, consequently, that the atmosphere rarely becomes saturated by the immediate effect of evaporation.

62. The state of saturation is, however, often attained either by loss of temperature, or by the intermixture of strata of air of different temperatures and differently charged with vapours. Thus, if air which is below the point of saturation suffer a loss of heat, its temperature may fall to that point which is the highest compatible with the density of the vapour actually suspended in it. The air will then become saturated, not by receiving any increased quantity of vapour, but by losing that caloric by which the vapour it contained was previously *superheated.*

If two strata of air at different temperatures, and both charged with vapour to a point below saturation, be intermingled, they will take an intermediate temperature, that which had the higher temperature imparting a portion of its heat to that which had a lower temperature. The vapour with which they were previously charged will likewise be intermixed and reduced to the common temperature. Now, in this case it may happen that the common temperature to which the entire mass is reduced, after intermixture, shall be either equal to or less than the greatest temperature compatible with the density of the vapour in the mass of air thus mixed. If it be equal to that temperature, the mass of air after intermixture will be *saturated*, though the strata before intermixture were both below saturation; and if less, condensation must take place until the density of the vapour suspended in the mixture be reduced to the greatest density compatible with the temperature.

It might be supposed that air and vapour being mixed together without combining chemically, would arrange themselves in strata, the lighter floating above the heavier as oil floats above water. This statical law, however, which prevails in liquids, is in the case of elastic fluids subject to important qualifications. The latter class of fluids have a tendency to intermingle and diffuse themselves through and among each other in opposition to their specific gravities. Thus if a stratum of hydrogen, the lightest of the gases, rest upon a stratum of carbonic acid, which is the heaviest, they will by slow degrees intermingle, a part of the hydrogen descending among the carbonic acid, and a part of the carbonic acid ascending among the hydrogen, and this will continue until the mixture becomes perfectly uniform, every part of it containing the two gases in the proportion of their entire quantities.

The same law prevails in the case of vapours mixed with gases; and thus may be explained the fact, that although the aqueous vapour suspended in the air, and having the same temperature, is always lighter bulk for bulk than the air, it does not ascend to the upper strata of the atmosphere, but is uniformly diffused through it.

63. It may be stated generally, that the effect of a column of air superposed upon the surface of water is only to retard, but not either to prevent or diminish, the evaporation. The same quantity of vapour will be developed as would be produced at the same temperature if no air were superposed on the water; but while in the latter case the entire quantity of vapour would be developed instantaneously, it is produced gradually, and completed only after a certain interval of time when the air is present. The quantity of vapour developed, and its density and pressure, are however exactly the same, whether the space through which it is diffused be a vacuum, or be filled by air, no matter what the density of the air may be. The properties of the air, therefore, neither modify nor are modified by those of the vapour which is diffused through it.

Since, at the same temperature and pressure, the density of the vapour of water is less than that of air in the ratio of 5 to 8, it follows that when air becomes charged with vapour of its own temperature, the volume will be augmented, but the density diminished. If a certain volume of air weigh 8 grains, an equal volume of vapour will weigh 5 grains, the two volumes mixed together will weigh 13 grains, and, consequently, an equal volume of the mixture will weigh $6\frac{1}{2}$ grains. In this case, therefore, the density of the air charged with vapour is less than the density of dry air of the same temperature in the ratio of $6\frac{1}{2}$ to 8.

64. The evaporation produced during the day by the action of solar heat on the surface of water, and on all bodies charged with moisture, causes the atmosphere at the time of sunset to be more or less charged with vapour, especially in the warm season. On hot days, and in the absence of winds, the atmosphere at sunset is generally at or near the point of saturation.

Immediately after sunset the temperature of the air falls. If it were previously in a state of saturation condensation must ensue, which will be considerable if the heat of the day and the consequent change of temperature after sunset be great. In such case, the vapour condensed often assumes the appearance of a fine rain or mist taking the liquid form before its actual deposition on the surface.

The deposition of dew, however, also takes place even where the atmosphere is not reduced to its point of saturation. When the firmament is unclouded after sunset, all objects which are good radiators of heat, among which the foliage and flowers of vegetables are the foremost, lose by radiation the heat which they had received before sunset without receiving any heat from the firmament sufficient to replace it. The temperature of such objects, therefore, falls much below that of the air, on which they produce an effect precisely similar to that which a glass of very cold water produces when exposed to a warm atmosphere charged with vapour. The air contiguous to their surface being reduced to the dew point by contact with them, a part of the vapour which it holds in suspension is condensed, and collects upon them in the form of dew.

It follows from this reasoning, that the dew produced by the fall of temperature of the air below the point of saturation will be deposited equally and indifferently on the surfaces of all objects exposed in the open air, but that which is produced by the loss of temperature of objects which radiate freely, will only be deposited on those surfaces which are good radiators. Foreign writers on physics accordingly class these depositions as different phenomena, the former being called by French meteorologists *serein*, and the latter *rosée* or dew. We are not aware that there is in English any term corresponding to *serein*.

Dew will fail to be deposited even on objects which are good radiators, when the firmament is clouded. For although heat be radiated as abundantly from objects on the surface of the earth as when the sky is unclouded, yet the clouds being also good radiators, transmit heat, which being absorbed by the bodies on the earth, compensates for the heat they lose by radiation, and prevents their temperature from falling so much below that of the air as to produce the condensation of vapour in contact with them.

Wind also prevents the deposition of dew by carrying off the air from contact with the surface of the cold object before condensation has time to take place. Meanwhile by the contact of succeeding portions of air, the radiator recovers its temperature.

In general, therefore, the conditions necessary to insure the deposition of dew is, 1st, a warm day to charge the air with vapour; 2nd, an unclouded night; 3rd, a calm atmosphere; and, 4th, objects exposed to it which are good radiators of heat.

In the close and sheltered streets of cities the deposition of dew is rarely observed, because there the objects are necessarily exposed to each other's influence, and an interchange of heat by radiation takes place so as to maintain their temperature; besides which, the objects found there are not as strong radiators as the foliage and flowers of vegetables.

65. When the cold which follows the condensation of vapour falls below 32°, what would otherwise be DEW becomes HOAR FROST. For the same reason that dew is deposited when the temperature of the air is above the point of saturation, hoar frost may be manifested when the temperature of the air is many degrees above the point of congelation; for in this case, as in that of dew, the objects on which the hoar frost collects lose so much heat by their strong radiation, that while the atmosphere may be above 40° they will fall below 32°. In such cases, a dew is first deposited upon them which soon congeals, and forms the needles and crystals with which every observer is familiar.

The hoar frost is sparingly or not at all formed upon the naked earth, or on stones or wood, while it is profusely collected on leaves and flowers. The latter are strong, the former feeble radiators.

Glass is a good radiator. The panes of a window fall during the night to a temperature below 32°, although the air of the room be at a much higher temperature. Condensation and a profuse deposition of moisture takes place on their inner surfaces, which soon congeals and exhibits the crystallised coating so often witnessed.

The frosts of spring and autumn, which so frequently are attended with injury to the crops of the farmer and gardener, proceed generally not from the congelation of moisture deposited from the atmosphere, but from the congelation of their own proper moisture by the radiation of their temperature caused by the nocturnal radiation, which in other cases produces dew or hoar frost. The young buds of leaves and flowers in spring, and the grain and fruit in autumn, being reduced by radiation below 32°, while the atmosphere is many degrees above that temperature, the water which forms part of their composition is frozen, and blight ensues.

These principles, which serve to explain the cause of the evil, also suggest its remedy. It is only necessary to shelter the object from exposure to the unclouded sky, which may be done by matting, gauze, and various other expedients.

66. In tropical climates the principle of nocturnal radiation has supplied the means of the artificial production of ice. This process, which is conducted on a considerable scale in Bengal, where some establishments for the purpose employ several hundred men, consists in placing water in shallow pans of unglazed pottery in a

situation which is exposed to the clear sky and sheltered from currents of air. Evaporation is promoted by the porous quality of the pans which become soaked with water, and radiation takes place at the same time both from the water and the pans. Both these causes combine in lowering the temperature of the water in the pans, which congeals when it falls below 32°.

67. When the steam issuing from the surface of warm water ascends into air which is at a lower temperature, it is condensed, but the particles of water formed by such condensation are so minute, that they float in the air as would the minute particles of an extremely fine dust. These particles lose their transparency by reason of their minuteness, according to a general law of physical optics. The vapour of water is transparent and colourless. It is only when it loses the character and qualities of true vapour, that it acquires the cloudy and semi-opaque appearance just mentioned.

Fogs are nothing more than such condensed vapour produced from the surface of seas, lakes, or rivers, when the water has a higher temperature than the stratum of air which rests upon it. These fogs are more thick and frequent when the air, besides having a lower temperature than the water, is already saturated with vapour, because in that case all the vapour developed must be immediately condensed, whereas, if the air be not saturated, it will absorb more or less of the vapour which rises from the water.

Clouds are nothing but fogs suspended in the more elevated strata of the atmosphere. Clouds are most frequently produced by the intermixture of two strata of air, having different temperatures and differently charged with vapour, the mixture being supersaturated, and therefore being attended with partial condensation as already explained.

68. When condensation of vapour takes place in the upper strata of the atmosphere, a fog or mist is first produced, after which the aqueous particles coalescing form themselves in virtue of the attraction of cohesion into spherules, and fall by their gravity to the earth, producing the phenomenon of rain.

69. The quantity of rain which falls in a given time at a given place, is expressed by stating the depth which it would have if it were received upon a plane and level surface, into which no part of it would penetrate.

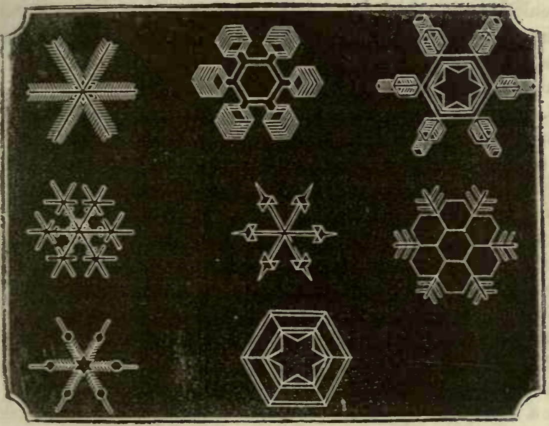
At Paris, the average annual quantity of rain which falls, obtained from observations continued for thirty years at the Observatory, is 23·6 inches. There is, however, considerable variation in the quantities from which this average is deduced; the smallest quantity observed being 16·9 inches, and the greatest 27·9 inches.

The greatest annual fall of rain is that observed at Maranham, lat. $2\frac{1}{2}°$ S., which is stated by Humboldt to amount to 277 inches, more than double the annual quantity hitherto observed elsewhere.

70. The physical conditions which determine the production of snow are not ascertained. It is not known whether the flakes as they fall are immediately produced by the congelation of condensed vapour in the cloud whence they first proceed, or whether being at first minute particles of frozen vapour, they coalesce with other frozen particles in falling through the successive strata of the air, and thus finally attain the magnitude which they have on reaching the ground.

The only exact observations which have been made on snow refer to the forms of the crystals composing it, which Captain Scoresby has observed with great accuracy in his "Polar Voyages," and of which he has given drawings. The flakes appear to consist of fine needles, grouped with singular symmetry. A few of the most remarkable forms are represented in fig. 2.

Fig. 2.



71. The physical causes which produce that formidable scourge of the agriculturist hail are uncertain. Hypotheses have been advanced to explain it which are more or less plausible, but which do not fulfil the conditions that would entitle them to the place of physical causes.

72. In the absence of any satisfactory explanation of the phenomenon, it is important to ascertain with precision and certainty the circumstances which attend it, and the conditions under which it is produced.

It may then, in the first place, be considered as certain that the formation of hail is an effect of sudden electrical changes in clouds charged with vapour; for there is no instance known of hail which is not either preceded or accompanied by thunder and lightning.

Before the fall of hail, during an interval more or less, but sometimes of several minutes' duration, a rattling noise is generally heard in the air, which has been compared to that produced by shaking violently bags of nuts.

Hail falls much more frequently by day than by night. Hail clouds have generally great extent and thickness, as is indicated by the obscuration they produce. They are observed also to have a peculiar colour, a gray having sometimes a reddish tint. Their form is also peculiar, their inferior surfaces having enormous protuberances, and their edges being indented and ragged.

These clouds are often at very low elevations. Observers on mountains very frequently see a hail cloud below them.

It appears, from an examination of the structure of hailstones, that at their centre there is generally an opaque nucleus, resembling the spongy snow that forms sleet. Round this is formed a congealed mass, which is semi-transparent. Sometimes this mass consists of a succession of layers or strata. These layers are sometimes all transparent, but in different degrees. Sometimes they are alternately opaque and semi-transparent.

73. Extraordinary reports of the magnitude of hailstones, which have fallen during storms so memorable as to find a place in general history, have come down from periods of antiquity more or less remote. According to the "Chronicles," a hailstorm occurred in the reign of Charlemagne, in which hailstones fell which measured fifteen feet in length by six feet in breadth, and eleven feet in thickness; and under the reign of Tippoo Saib, hailstones equal in magnitude to elephants are said to have fallen. Setting aside these and like recitals, as partaking rather of the character of fable than of history, we shall find sufficient to create astonishment in well authenticated observations on this subject.

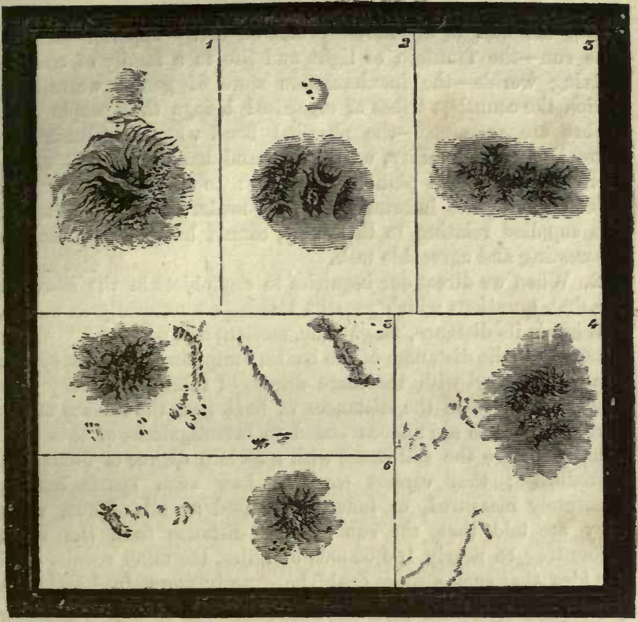
In a hailstorm which took place in Flintshire on the 9th April, 1697, Halley saw hailstones which weighed five ounces.

On the 4th May, 1697, Robert Taylor saw fall hailstones measuring fourteen inches in circumference.

In the storm which ravaged Como on 20th August, 1787, Volta saw hailstones which weighed nine ounces.

On 22nd May, 1822, Dr. Noggerath saw fall at Bonn hailstones which weighed from twelve to thirteen ounces.

It appears, therefore, certain that in different countries hailstorms have occurred in which stones weighing from half to three quarters of a pound have fallen.




SOLAR SPOTS OBSERVED IN 1826 AND 1828 BY MM. CAPOCCI AND PASTORFF.

Capocci—1. Sept. 29; 2. Sept. 2; 3. July 1, 1826.
Pastorff—4. Sept. 27, 1826; 5. May 21; 6. June 21, 1828.

# THE SUN.

1. An object of great interest.—2. Its distance.—3. Magnitude.—4. Illustrations.—5. Its volume.—6. Mass or weight.—7. How ascertained.—8. Application of this principle.—9. Its density.—10. Form and rotation.—11. Determined by the appearance of spots.—12. Discovery of Solar spots.—13. Their great magnitude.—14. Their rapid changes.—15. Hypotheses to explain them.—16. They are excavations in the luminous coating.—17. Their prevalence varies.—18. Observations upon them.—19. Their dimensions.—20. Facules and Lucules.—21. Physical state of the Solar surface.—22. Luminous coating is gaseous.—23. Gaseous atmosphere outside it.—24. Effects of such an atmosphere on radiation.—25. Hypothesis of Sir J. Herschel.—26. Intensity of heat at Sun's surface.—27. Supposed source of heat.

1. Although perhaps the moon is the object among the heavenly bodies which presents the subject of most interesting inquiry to the world in general, yet, to the thoughtful and contemplative

mind, the sun is undoubtedly one of vastly superior interest. The sun—the fountain of light and life to a family of circumvolving worlds—the inexhaustible store of genial warmth by which the countless tribes of organised beings that people these globes are sustained—the physical bond whose predominating attraction gives stability, uniformity, and harmony, to the movements of the entire planetary system: to collect together in a brief compass the information which modern scientific research has supplied relating to this body, cannot be otherwise than an interesting and agreeable task.

2. When we direct our inquiries to any object in the heavens, the first questions which present themselves naturally to us are, "What is its distance, magnitude, motion, and position?" When we say that the distances of the bodies composing the solar system can be measured with the same degree of relative accuracy with which we ascertain the distances of bodies on the surface of the earth, those who are unaccustomed to investigations of this kind usually receive the statement with a certain degree of doubt and incredulity; they cannot conceive how such spaces can be accurately measured, or indeed measured at all. Thus, when they are told that the sun is at a distance from the earth amounting to nearly 100,000000 of miles, the mind revolts from the idea that such a space could be exactly ascertained and estimated. Yet, let us ask, why this difficulty? whence this incredulity? Is it because the distance thus measured is enormously great,—greater transcendently than any distance we are accustomed to contemplate upon our own globe? To this we reply that the magnitude of a distance or space does not constitute of itself any difficulty in its admeasurement. Nay, on the contrary, it is often the case that we are able to measure large distances with greater relative accuracy than small ones; this is frequently so in the surveys conducted on the surface of our own globe. If, then, the greatness of the magnitudes does not constitute of itself any difficulty, to what are we to ascribe the doubt entertained by the popular mind in regard to such measurement? It will, perhaps, be replied that the object, whose distance we claim to have measured, is inaccessible to us; that we cannot travel over the intermediate space, and therefore cannot be conceived to measure it. But again, let us ask whether this circumstance of being inaccessible constitutes any real difficulty in the measurement of the distance of an object? The military engineer, who directs his projectiles against the buildings within a town which is besieged, can, as we well know, level them so as to cause a shell to drop on any individual building which may have been chosen. To do this, he must know the exact distance of the building from

the mortar. Yet the building is inaccessible to him; the walls of the town, the fortifications, and perhaps a river, intervene. He finds, however, no difficulty in measuring the distance of this inaccessible building. To accomplish this, he lays down a space upon the ground he occupies, called the *base* line, from the extremities of which he takes the bearings or directions of the building in question. From these bearings, and from the length of the base line, he is enabled to calculate by the most simple principles of geometry and arithmetic the distance of the building in question. Now imagine the building in question to be the sun, and the base line to be the whole diameter of the globe of the earth, in what respect would the problem be altered? The building within the town is inaccessible—so is the sun; the base line of the engineer is exactly known—so is the diameter of the earth; the bearings of the building from the ends of the base line are known —so are the bearings of the sun's centre from the extremes of the earth's diameter. The problems are, in fact, identical; they differ in nothing except the accidental and unimportant circumstance of the magnitudes of the lines and angles that enter the question. In short, the measurement of distances of objects in the heavens is effected upon principles in all respects similar to those which govern the measurement of distances upon the earth; nor are they attended with a greater difficulty, or more extensive sources of error.

By such means of observation and calculation it has been ascertained that the sun's distance from the earth is a little less than an hundred millions of miles. Although such calculations supply results having surprising arithmetical accuracy, the ordinary student will always find it convenient to register in his memory the results in the nearest round numbers, and it is not easy to forget that the distance of the sun, the most important of all astronomical measurements, is very nearly an hundred millions of miles.

But while this round result is remembered, it will also be useful to explain the more exact numerical measure of this distance, and the limits of the error to which it is subject. The result of the most exact observations made upon the different bearings of lines drawn from opposite sides of the earth to the sun, gives as the distance of that luminary,

95,293452 miles,

and it has been proved that this result cannot be greater or less than the true distance by more than its three hundredth part. We are, therefore, enabled to affirm absolutely that the distance of the sun cannot be greater than

$$95,293452 + 317645 = 95,611097 \text{ miles};$$

or less than

$$95,293452 - 317645 = 94,975807 \text{ miles}.$$

Since the sun moves over 360° of the heavens in $365\frac{1}{4}$ days, its daily apparent motion must be $59'\cdot14$, or $3548''$, which being about twice the sun's apparent diameter, it is easy to remember that the disk of the sun appears to move in the firmament daily over a space nearly equal to twice its own apparent diameter. Its hourly apparent motion is

$$\frac{3548''}{24}=147''\cdot8.$$

3. Having explained the distance of the sun, let us now see how its magnitude can be ascertained. There is one general principle by which the magnitudes of all the heavenly bodies can be ascertained when their distance is known. This is, in fact, accomplished by the device of comparing them with some object of known magnitude and which at any known distance will have the same apparent size. As this is important, considered as a general principle applied to all objects in the heavens, it may not be uninteresting to develop it somewhat fully in its application to the present object, the sun.

The common observation of every one who directs his view to the heavens, will inform him of the fact that the sun and full moon appear to be of the same size. The mere effect of ordinary visual observation is, perhaps, enough to establish this; but if more be desired, instruments expressly adapted to measure the apparent magnitudes of objects may be applied. We are also confirmed in the fact by the consideration of the well-known phenomena of solar eclipses. A solar eclipse is produced by the interposition of the globe of the moon between the eye and the globe of the sun. The eclipse is said to be central when the centre of the moon is directly in line between the eye and the centre of the sun. When this takes place we find that the globe of the moon generally covers pretty exactly that of the sun. Owing, however, to a slight variation in the apparent size of these bodies, from a cause that we shall explain on another occasion, the moon at one time a little more than covers the sun, and at another time a little less. In short, the average apparent magnitudes of these bodies are the same, the one exactly covering or concealing the other.

But we have already stated that the distance of the moon is only a quarter of a million of miles. And since that of the sun is an hundred millions of miles, it appears that the distance of the sun is four hundred times greater than that of the moon; yet these two globes appear to the eye to be of the same magnitude. The sun, notwithstanding its being four hundred times farther off, appears just as large as the moon. What, then, are we to infer respecting its real magnitude? If the sun were really equal in magnitude to the moon, it would assuredly appear four hundred times less at four hundred times a greater distance: but since at that greater distance it does not appear less or greater, but of the same magnitude, the irresistible conclusion, level to the apprehension of any understanding, is, that the sun must in reality be four hundred times greater in its diameter than the moon. If it were less, at four hundred times the moon's distance, it would appear less than that of the moon; if it were greater, at that distance it would appear greater. It follows, then, that whatever be the magnitude of the diameter of the moon, the diameter of the sun must assuredly be four hundred times greater. Now it has been ascertained by absolute measurement that the diameter of the moon measures about 2000 miles. If we multiply this by four hundred we shall obtain 800000 miles, which is, therefore, the diameter of the sun.

These calculations have been made roughly and in round numbers; more accurately, the diameter of the sun measures 882000 miles, but as we recommend the adoption of round numbers, we shall call the sun's diameter 900000 miles. Such is the stupendous mass placed in the centre of the system which, by its attraction, coerces the movements of the planets.

4. Such magnitudes and distances are so far beyond all the ordinary standards with which we are familiar, that the imagination is confounded and falls back upon itself after any effort to form a distinct conception of them. Let us see whether we cannot discover some expedient or some means of illustration by which a more distinct notion can be obtained of the distance and magnitude of this stupendous globe.

A railway-train moving at thirty-two miles an hour would take three millions of hours or an hundred and twenty-five thousand days, or three hundred and forty-two years and three months to move from the earth to the sun, supposing it to travel incessantly night and day for that time!

A cannon ball moves fifty times as fast as such a railway train. It would therefore move to the sun in a little less than seven years!

To give some idea of the dimensions of the sun we are to consider that having a diameter of 882000 miles, its circumference will be about 2,770000 miles. Such a railway-train would take nine years and ten months to travel round it.

We know that the moon revolves in a circle round the earth at the distance of nearly a quarter of a million of miles. Now let us suppose the earth to be placed at the centre of the sun. The distance of the outer surface of the sun from the centre of the earth would be 441000 miles. Now the circle in which the moon revolves round the earth, is at a distance of 240000 miles from its centre, consequently it follows that the earth and moon would be not only contained within the globe of the sun, but the moon would be a couple of hundred thousand miles within the sun's surface.

5. But we have hitherto only spoken of the diameter of the sun; let us now consider its bulk. When we know the diameters of two globes we can always, by an easy operation of arithmetic, estimate their bulks. Thus, if one globe have a diameter double another, the bulk of the former will be eight times that of the latter. If the diameter be ten times greater, the bulk will be a thousand fold greater, and so on. Now we know that the diameter of the sun is about one hundred and twelve times greater than that of the earth, from which we infer, by the same principles of arithmetic, that the bulk of the sun must be very nearly one million four hundred thousand times the bulk of the earth. To make a globe like the sun, it would then be necessary to roll one million four hundred thousand globes like the earth into one! It is found by considering the bulks of the different planets, that if all the planets and satellites in the solar system were moulded into a single globe, that globe would still not exceed the five hundredth part the globe of the sun: in other words, the bulk of the sun is five hundred times greater than the aggregate bulk of all the rest of the bodies of the system.

6. The astronomer, however, is called upon to execute processes more difficult and yet no less indispensable than the mere measurement of distances and magnitudes. If we desire to know the quantities of matter composing those distant orbs, we must not merely measure their magnitudes and fathom their distances, but we must wing our flight, in imagination, across those vast distances which separate us from them and *weigh* their stupendous masses. If the popular student finds it difficult to believe and comprehend how we can measure distances and magnitudes such as those of the heavenly bodies, how much more will he be confounded when he is assured that we have at our disposal a balance of the most unerring exactitude in which we can place those vast orbs and poise them! The globe of the sun itself, transcendently greater than the earth and all the planets put together, is weighed with as great relative precision, as that with which the chemist in his analysis, estimates the weights of the constituents of the bodies which pass under his hands. As the general principles by which the weights of the bodies of the universe are ascertained is in spirit the same for all, it may be worth while here to explain the method, once for all, in its application to the sun.

7. When a body revolves in a circle, we know from common

and familiar experiments that it has a tendency to fly from the centre, which tendency is greater the more rapidly the body revolves and the greater its distance from the centre. The boy who whirls a stone in a sling is conscious of this physical truth. The stone, as it revolves, stretches the string with a certain definite force; this force is not in the gravity of the stone, for it would be equally manifested if the stone revolved in a horizontal plane. It is that tendency which we have just adverted to, and which is technically called centrifugal force. If you increase the velocity with which the stone is whirled round, you will find the string will be more and more tightly stretched, and you may augment the velocity to such an extent as to break the string. If you lengthen or shorten the string, preserving the same velocity of rotation, you will find that the tendency to stretch the string will be proportionally increased or diminished; in short, a fixed rule or *law*, as it is called, will be easily discovered by a series of simple experiments which will enable us to predict how much the string will be stretched, provided we know the distance of the revolving weight from the centre of the circle and the time it takes to make each revolution.

8. To apply this general principle, then, to the case before us, let it be considered that the moon in its monthly course revolves in a circle round the centre of the earth. We know its distance, and we know the time which it takes to make each revolution, we are therefore in a condition to declare with what force it would stretch a string, tying it to the centre of the earth. That the moon exercises such a force cannot then be doubted. But on what, it will be asked, is that force expended? There is no string, rod, or any other material or tangible connection between the moon and the centre of the earth. And yet the moon is held as firmly and steadily in its circular course round the earth, as if it were tied to the centre by a string. In the absence of the string there must then be some physical agency which plays its part; there must be something to resist that tendency which the string, if there, would have resisted. That *something* was discovered by Newton to be the attraction of the earth's GRAVITATION exercised upon the moon and holding the moon in its circular orbit, in the same manner that it would be held by the string which has been just described. As we know, by the simple mechanical law above explained, the force with which that string would be stretched by the moon in this case, we are enabled by the same principle to say what is the amount of attractive force which the earth exercises upon the moon to keep it in its monthly orbit.

In this manner, in general, we are enabled to estimate the force of attraction which a central mass exercises upon another body revolving in a circle round it at a known distance, and in a known time.

While, on the one hand, we know the distance and time of the moon's revolution round the earth, we also know the distance and time of the earth's revolution round the sun. We are thus, allowing for the difference of the two distances, in a condition to compare the actual amount of attraction which the earth and the sun respectively exercise upon bodies revolving round them, and we find, accordingly, that the attraction exercised by the sun upon any body is greater than the attraction that would be exercised by the earth upon the same body in a like position, in the proportion of three hundred and fifty thousand to one. But as these attractions are, in fact, produced by the respective masses of matter composing the sun and the earth, it follows that the weight of the sun, or what is the same, the mass of matter composing it, is three hundred and fifty thousand times greater than the mass of matter or weight of the earth.

To make a globe as heavy as the sun, it would then be necessary to agglomerate into one three hundred and fifty thousand globes like the earth.

9. Having ascertained the weights and bulks of the bodies of the universe, we are in a condition to determine their densities, and thus to obtain some clue to a knowledge of their constituent materials. We have seen that while the bulk of the sun is about one million and four hundred thousand times greater than that of the earth, its weight is greater in the much less proportion of three hundred and fifty thousand to one. Let us see to what inference this leads in regard to the nature of the matter that composes the sun. If the materials of the sun were similar to those of the earth, its weight would necessarily be greater than that of the earth in the same proportion as its bulk, and in that case, of course, the weight of the sun would be one million and four hundred thousand times that of the earth. But it is not nearly so great as this; on the contrary, it is much less. Consequently, it follows that the constituent materials of the sun are lighter than those of the earth in the proportion of about four to one. The density of the sun is, therefore, about forty per cent. greater than that of water, and, consequently, the weight of the solar orb exceeds the weight of a globe of the same magnitude composed altogether of water, only in that proportion.

10. Although to minds unaccustomed to the rigour of scientific research, it might appear sufficiently evident, without further demonstration, that the sun is globular in its form, yet the more exact methods pursued in the investigation of physics demand that we should find more conclusive proof of the sphericity of the

solar orb than the mere fact that the disc of the sun is always circular. It is barely possible, however improbable, that a flat circular disc of matter, the face of which should always be presented to the earth, might be the form of the sun; and indeed there are a great variety of other forms which, by a particular arrangement of their motions, might present to the eye a circular appearance as well as a globe or sphere. To prove, then, that a body is globular, something more is necessary than the mere fact that it always appears circular.

11. When a telescope is directed to the sun, we discover upon it certain marks or spots, of which we shall speak more fully presently. We observe that these marks, while they preserve the same relative position with respect to each other, move regularly from one side of the sun to the other. They disappear, and continue to be invisible for a certain time, come into view again on the other side, and so once more pass over the sun's disc. This is an effect which would evidently be produced by marks on the surface of a globe, the globe itself revolving on an axis, and carrying these marks upon it. That this is the case, is abundantly proved by the fact that the periods of rotation for all these marks are found to be exactly the same, viz., about twenty-five and a half days. Such is, then, the time of rotation of the sun upon its axis, and that it is a globe remains no longer doubtful, since the globe is the only body which, while it revolves with a motion of rotation, could always present the circular appearance to the eye. The axis on which the sun revolves is very nearly perpendicular to the plane of the earth's orbit, and the motion of rotation of the sun upon the axis is in the same direction as the motion of the planets round the sun, that is to say, from west to east.

12. One of the earliest fruits of the invention of the telescope was the discovery of the spots upon the sun, and the examination of these has gradually led to a knowledge of the physical constitution of the centre of our system.

When we submit a solar spot to telescopical examination, we discover its appearance to be that of an intensely black irregularly-shaped patch, edged with a penumbral fringe, the brightness of the general surface of the sun gradually fading away into the blackness of the spot. When watched for a considerable time, it is found to undergo a gradual change in its form and magnitude; at first increasing in size, until it attains some definite limit of magnitude, when it ceases to increase, and soon begins, on the contrary, to diminish; and its diminution goes on gradually, until at length the bright edges closing in upon the dark patch, it dwindles first to a mere point, and finally disappears altogether.

The period which elapses between the formation of the spot, its gradual enlargement, subsequent diminution, and final disappearance, is very various. Some spots appear and disappear very rapidly, while others have lasted for weeks and even for months.

13. The magnitudes of the spots, and the velocities with which the matter composing their edges and fringes moves, as they increase and decrease, are on a scale proportionate to the dimensions of the orb of the sun itself. When it is considered that a space upon the sun's disc, the apparent breadth of which is only a minute, actually measures 27960 miles, and that spots have been frequently observed, the apparent length and breadth of which have exceeded 2′, the stupendous magnitude of the regions they occupy may be easily conceived.

14. The velocity with which the luminous matter at the edges of the spots occasionally moves, during the gradual increase or diminution of the spot, has been in some cases found to be enormous. A spot, the apparent breadth of which was 90″, was observed by Mayer to close in about 40 days. Now, the actual linear dimensions of such a spot must have been 41940 miles, and consequently, the average daily motion of the matter composing its edges must have been 1050 miles, a velocity equivalent to forty-four miles an hour.

15. Two, and only two, suppositions have been proposed to explain the spots. One supposes them to be scoriæ, or dark scales of incombustible matter, floating on the general surface of the sun. The other supposes them to be excavations in the luminous matter which coats the sun, the dark part of the spot being a part of the solid non-luminous nucleus of the sun. In this latter hypothesis it is assumed that the sun is a solid non-luminous globe, covered with a coating of a certain thickness of luminous matter.

That the spots are excavations, and not mere black patches on the surface, is proved by the following observations: If we select a spot which is at the centre of the sun's disc, having some definite form, such as that of a circle, and watch its changes of appearance, when, by the rotation of the sun, it is carried towards the edge, we find, first, that the circle becomes an oval. This, however, is what would be expected, even if the spot were a circular patch, inasmuch as a circle seen obliquely is foreshortened into an oval. But we find that as the spot moves towards the side of the sun's limb, the black patch gradually disappears, the penumbral fringe on the inside of the spot becomes invisible, while the penumbral fringe on the outside of the spot increases in apparent breadth, so that when the spot approaches the edge of the sun, the only part that is visible is the external penumbral fringe. Now, this is exactly what would occur if the spot were an excavation. The penumbral fringe is produced by the shelving of the sides of the excavation, sloping down to its dark bottom. As the spot is carried toward the edge of the sun, the height of the inner side is interposed between the eye and the bottom of the excavation, so as to conceal the latter from view. The surface of the inner shelving side also taking the direction of the line of vision or very nearly, diminishes in apparent breadth, and ceases to be visible, while the surface of the shelving side next the edge of the sun becoming nearly perpendicular to the line of vision, appears of its full breadth.

In short, all the variations of appearance which the spots undergo, as they are carried round by the rotation of the sun, changing their distances and positions with regard to the sun's centre, are exactly such as would be produced by an excavation, and not at all such as a dark patch on the solar surface would undergo.

16. It may be considered then as proved, that the spots on the sun are excavations; and that the apparent blackness is produced by the fact that the part constituting the dark portion of the spot is either a surface totally destitute of light, or by comparison so much less luminous than the general surface of the sun, as to appear black. This fact, combined with the appearance of the penumbral edges of the spots, has led to the supposition, advanced by Sir W. Herschel, which appears scarcely to admit of doubt, that the solid, opaque nucleus, or globe of the sun, is invested with at least two atmospheres, that which is next the sun being, like our own, non-luminous, and the superior one being that alone in which light and heat are evolved; at all events, whether these strata be in the gaseous state or not, the existence of two such, one placed above the other, the superior one being luminous, seems to be exempt from doubt.

We are not warranted in assuming that the black portion of the spots are surfaces really deprived of light, for the most intense artificial lights which can be produced, such, for example, as that of a piece of quicklime exposed to the action of the compound blow-pipe, when seen projected on the sun's disk, appear as dark as the spots themselves; an effect which must be ascribed to the infinitely superior splendour of the sun's light. All that can be legitimately inferred respecting the spots, then, is, not that they are destitute of light, but that they are incomparably less brilliant than the general surface of the sun.

17. The prevalence of spots on the sun's disk is both variable and irregular. Sometimes the disk will be completely divested of them, and will continue so for weeks or months; sometimes they will be spread over certain parts of it in profusion. Sometimes the spots will be small, but numerous; sometimes individual spots will

appear of vast extent; sometimes they will be manifested in groups, the penumbræ or fringes being in contact.

The duration of each spot is also subject to great and irregular variation. A spot has appeared and vanished in less than twenty-four hours, while some have maintained their appearance and position for nine or ten weeks, or during nearly three complete revolutions of the sun upon its axis.

A large spot has sometimes been observed suddenly to crumble into a great number of small ones.

The only circumstance of regularity which can be said to attend these remarkable phenomena is their position upon the sun. They are invariably confined to two moderately broad zones parallel to the solar equator, separated from it by a space several degrees in breadth. The equator itself, and this space which thus separates the macular zones, are absolutely divested of such phenomena.

18. Observations upon the appearances from which these inferences have been made, have been at various times made by astronomers, the most important being those of Sir William Herschel, Dr. Pastorff, Professor Capocci, and Sir J. Herschel, who have severally supplied drawings of their appearance, the general similarity of which, made at different places of observation, at very different times, and by different observers, offers a strong evidence of their authenticity.

In the figure at the head of this chapter, we have given copies of several of the most remarkable of these drawings.

19. The superficial dimensions of the several groups of spots observed on the sun on the 24th May, 1828, including the shelving sides, were calculated to be as follows :—

| | Square Geog. miles. |
|---|---|
| Group A, principal spot . . . . . . | 928,000000 |
| Ditto, smaller spots . . . . . . . | 736,000000 |
| Group B . . . . . . . . . . | 296,000000 |
| Group C . . . . . . . . . . | 232,000000 |
| Group D . . . . . . . . . . | 304,000000 |
| Total area . . . | 2496,000000 |

20. Independently of the dark spots just described, the luminous part of the solar disk is not uniformly bright. It presents a mottled appearance, which may be compared to that which would be presented by the undulated and agitated surface of an ocean of liquid fire, or to a stratum of luminous clouds of varying depth, and having an unequal surface, or the appearance produced by the slow subsidence of some flocculent chemical precipitates in a transparent fluid, when looked at perpendicularly from above. In the space immediately around the edges of the spots extensive

spaces are observed, also covered with strongly defined curved or branching streaks, more intensely luminous than the other parts of the disk, among which spots often break out. These several varieties in the intensity of the brightness of the disk have been differently designated by the terms *facules* and *lucules*. These appearances are generally more prevalent and strongly marked near the edges of the disk.

21. Various attempts have been made to ascertain by the direct test of observation, independently of conjecture or hypothesis, the physical state of the luminous matter which coats the globe of the sun, whether it be solid, liquid, or gaseous.

That it is not solid is admitted to be proved conclusively by its extraordinary mobility, as indicated by the rapid motion of the edges of the spots in closing; and it is contended that a fluid capable of moving at the rate of 44 miles per hour cannot be supposed to be liquid, an elastic fluid alone admitting of such a motion.

Arago has, however, suggested a physical test, by which it appears to be proved that this luminous matter must be gaseous; in short, that the sun must be invested with an ocean of flame, since flame is nothing more than aëriform fluid in a state of incandescence. This test proposed is based upon the properties of polarised light.

It has been proved that the light emitted from an incandescent body in the liquid or solid state, issuing in directions very oblique to the surface, even when the body emitting it is not smooth or polished, presents evident marks of polarisation, so that such a body, when viewed through a polariscopic telescope, will present two images in complementary colours. But, on the other hand, no signs of polarisation are discoverable, however oblique may be the direction in which the rays are emitted, if the luminous matter be flame.

The light proceeding from the disk of the sun has been accordingly submitted to this test. The rays proceeding from its borders evidently issue in a direction as oblique as possible to the surface, and therefore, under the condition most favourable to polarisation, if the luminous matter were liquid. Nevertheless, the borders of the double image produced by the polariscope show no signs whatever of complementary colours, both being equally white even at the very edges.

This test is only applicable to the luminous matter at or near the edge of the disk, because it is from this only that the rays issue with the necessary obliquity. But since the sun revolves on its axis, every part of its surface comes in succession to the edge of the disk; and thus it follows that the light emanating from every part of it is in its natural or unpolarised state, even when issuing at the greatest obliquity; and, consequently, that the luminous matter is everywhere gaseous.

22. All the phenomena which have been here described, and others which our limits compel us to omit, are considered as giving a high degree of physical probability to the hypothesis of Sir W. Herschel already noticed, in which the sun is considered to be a solid, opaque, non-luminous globe invested by two concentric strata of gaseous matter, the first, or that which rests immediately on the surface, being non-luminous, and the other, which floats upon the former, being luminous gas or flame. The relation and arrangement of these two fluid strata may be illustrated by our own atmosphere, supporting upon it a stratum of clouds. If such clouds were flame, the condition of our atmosphere would represent the two strata on the sun.

The spots in this hypothesis are explained by occasional openings in the luminous stratum by which parts of the opaque and non-luminous surface of the solid globe are disclosed. These partial openings may be compared to the openings in the clouds of our sky, by which the firmament is rendered partially visible.

23. Many circumstances supply indications of the existence of a gaseous atmosphere of great extent above the luminous matter which forms the visible surface of the sun. It is observed that the brightness of the solar disk is sensibly diminished towards its borders. This effect would be produced if it were surrounded by an imperfectly transparent atmosphere, whereas if no such gaseous medium surrounded it, the reverse of such an effect might be expected, since then the thickness of the luminous coating measured in the direction of the visual ray would be increased very rapidly in proceeding from the centre towards the edges. This gradual diminution of brightness in proceeding towards the borders of the solar disk has been noticed by many astronomers; but it was most clearly manifested in the series of observations made by Sir J. Herschel in 1837, so conclusively, indeed, as to leave no doubt whatever of its reality on the mind of that eminent observer. By projecting the image of the sun's disk on white paper by means of a good achromatic telescope, this diminution of light towards the borders was on that occasion rendered so apparent, that it appeared to him surprising that it should ever have been questioned.

But the most conclusive proofs of the existence of such an external atmosphere are supplied by certain phenomena observed on the occasion of total eclipses of the sun, which will be fully explained in another part of this series.

24. The heat generated by some undiscovered agency upon the

sun is dispersed through the surrounding space by radiation. If, as may be assumed, the rate at which this heat is generated be the same on all parts of the sun, and if, moreover, the radiation be equally free and unobstructed from all parts of its surface, it is evident that a uniform temperature must be everywhere maintained. But if, from any local cause, the radiation be more obstructed in some regions than in others, heat will accumulate in the former, and the local temperature will be more elevated there than where the radiation is more free.

But the only obstruction to free radiation from the sun must arise from the atmosphere with which to an height so enormous it is surrounded. If, however, this atmosphere have everywhere the same height and the same density, it will present the same obstruction to radiation, and the effective radiation which takes place through it, though more feeble than that which would be produced in its absence, is still uniform.

But since the sun has a motion of rotation on its axis in $25^{d.}\ 7^{h.}\ 48^{m.}$, its atmosphere, like that of the earth, must participate in that motion and the effects of centrifugal force upon matter so mobile: the equatorial zone being carried round with a velocity greater than 300 miles per second, while the polar zones are moved at a rate indefinitely slower, all the effects to which the spheroidal form of the earth is due will affect this fluid with an energy proportionate to its tenuity and mobility, the consequence of which will be that it will assume the form of an oblate spheroid, whose axis will be that of the sun's rotation. It will flow from the poles to the equator, and its height over the zones contiguous to the equator will be greater than over those contiguous to the poles, in a degree proportionate to the ellipticity of the atmospheric spheroid.

Now, if this reasoning be admitted, it will follow that the obstruction to radiation produced by the solar atmosphere is greatest over the equator, and gradually decreases in proceeding towards either pole. The accumulation of heat, and consequent elevation of temperature, is, therefore, greatest at the equator, and gradually decreases towards the poles, exactly as happens on the earth from other and different physical causes.

25. The effects of this inequality of temperature, combined with the rotation, upon the solar atmosphere, will of course be similar in their general character, and different only in degree from the phenomena produced by the like cause on the earth. Inferior currents will, as upon the earth, prevail towards the equator, and superior counter-currents towards the poles. The spots of the sun would, therefore, be assimilated to those tropical regions of the earth in which, for the moment, hurricanes and tornadoes prevail, the upper stratum which has come from the equator being

temporarily carried downwards, displacing by its force the strata of luminous matter beneath it (which may be conceived as forming an habitually tranquil limit between the opposite upper and under currents), the upper of course to a greater extent than the lower, and thus wholly or partially denuding the opaque surface of the sun below. Such processes cannot be unaccompanied by vorticose motions, which, left to themselves, die away by degrees, and dissipate, with this peculiarity, that their lower portions come to rest more speedily than their upper, by reason of the greater distance below, as well as the remoteness from the point of action, which lies in a higher region, so that their centre (as seen in our water-spouts, which are nothing but small tornadoes) appears to retreat upwards.*

Sir J. Herschel maintains that all this agrees perfectly with what is observed during the obliteration of the solar spots, which appear as if filled in by the collapse of their sides, the penumbra closing in upon the spot and disappearing afterwards.

It would have rendered this ingenious hypothesis still more satisfactory, if Sir J. Herschel had assigned a reason why the luminous and subjacent non-luminous atmosphere, both of which are assumed to be gaseous fluids, do not affect, in consequence of the rotation, the same spheroidal form which he ascribes to the superior solar atmosphere.

26. It has been shown that the intensity of heat on the sun's surface must be seven times as great as that of the vivid ignition of the fuel in the strongest blast furnace. This power of solar light is also proved by the facility with which the calorific rays pass through glass. Herschel found, by experiments made with an actinometer, that 81·6 per cent of the calorific rays of the sun penetrate a sheet of plate-glass 0·12 inch thick, and that 85·9 per cent. of the rays which have passed through one such plate will pass through another.†

27. One of the most difficult questions connected with the physical condition of the sun, is the discovery of the agency to which its heat is due. To the hypothesis of combustion, or any other which involves the supposition of extensive chemical change in the constituents of the surface, there are insuperable difficulties. Conjecture is all that can be offered, in the absence of all data upon which reasoning can be based. Without any chemical change, heat may be indefinitely generated either by friction or by electric currents, and each of these causes have accordingly been suggested as a possible source of solar heat and light. According to the latter hypothesis, the sun would be a great ELECTRIC LIGHT in the centre of the system.

* Herschel's Cape Observations, p. 434. † Ibid., p. 133.

INSTRUMENT ROOM, ELECTRIC TELEGRAPH OFFICE, CHARING CROSS.

# THE ELECTRIC TELEGRAPH.

## CHAPTER I.

1. Subjugation of the powers of nature to human uses.—2. Locomotion twenty years since.—3. Circulation of intelligence then.—4. Supposed prediction of succeeding improvements—Railway locomotion.—5. Electric telegraphy.—6. Fabrication of diamonds—sun pictures—gas-lighting—electro-metallurgy.—7. Such predictions would have been deemed incredible.—8. Electro-telegraphy the most incredible of all.—9. Remarkable experiment by Messrs. Leverrier and Lardner.—10. Velocity of electric current.—11. No limit to the celerity of telegraphy.—12. Physical character of electricity.—13. Not essential to the explanation of electro-telegraphy.—14. Electricity a subtle fluid.—15. Properties available for telegraphy.—16. Voltaic battery.—17 It is to the electric telegraph what the boiler is to the steam-engine.—18. Means of transmitting the fluid in required directions.—19. Conductors and insulators.—20. Conducting wires.—21. Voltaic battery.—22. Transmission and suspension of the current.—23. Current established by earth contact.—24. Theories of earth contact.—25. The return of the current through the earth.—26. Various bodies

evolve electricity.—27. Common plate battery of zinc and copper. —28. Why zinc and copper are preferred.—29. Charcoal substituted for copper.—30. Elements not essential.—31. Various chemical solutions used.—32. Daniel's constant battery.—33. Same modified by Pouillet.—34. Grove's and Bunsen's batteries.—35. Necessary to combine many elements.

1. Each succeeding age and generation leaves behind it a peculiar character, which stands out in relief upon its annals, and is associated with it for ever in the memory of posterity. One is signalised for the invention of gunpowder, another for that of printing; one is rendered memorable by the revival of letters, another by the reformation of religion; one is marked in history by the conquests of Napoleon, another is rendered illustrious by the discoveries of Newton.

If we are asked by what characteristic the present age will be marked in future records, we answer, by the miracles which have been wrought in the subjugation of the powers of the material world to the uses of the human race. In this respect no former epoch can approach to competition with it.

The author of some of the most popular fictions of the day has affirmed, that in adapting to his purpose the results of his personal observation on men and manners, he has not unfrequently found himself compelled to mitigate the real in order to bring it within the limits of the probable. No observer of the progress of the arts of life, at the present time, can fail to be struck with the prevalence of the same character in their results as that which compelled this writer to suppress the most wonderful of what had fallen under his eye, in order to bring his descriptions within the bounds of credibility.

2. Many are old enough to remember the time when persons, correspondence, and merchandise were transported from place to place in this country by stage-coaches, vans, and waggons. In those days the fast-coach, with its team of spanking blood-horses, and its bluff driver, with broad-brimmed hat and drab box-coat, from which a dozen capes were pendant, who "*handled the ribbons*" with such consummate art, could pick a fly from the ear of the off-leader, and turn into the gateway at Charing Cross with the precision of a geometrician, were the topics of the unbounded admiration of the traveller. Certain coaches obtained a special celebrity and favour with the public. We cannot forget how the eye of the traveller glistened when he mentioned the Brighton "Age," the Glasgow "Mail," the Shrewsbury "Wonder," or the Exeter "Defiance,"—the "Age," which made its trip in five hours, and the "Defiance," which acquired its fame by completing the journey between London and Exeter in less than thirty hours.

3. The rapid circulation of intelligence was also the boast of those times. How foreigners stared when told that the news of each afternoon formed a topic of conversation at tea-tables the same evening, twenty miles from London, and that the morning journals, still damp from the press, were served at breakfast within a radius of thirty miles, as early as the frequenters of the London clubs received them.

Now let us imagine that some profound thinker, deeply versed in the resources of Science at that epoch, were to have gravely predicted that the generation existing then and there would live to see all these admirable performances become obsolete, and consigned to the history of the past; that they would live to regard such vehicles as the "Age" and "Defiance" as clumsy expedients, and their celerity such as to satisfy those alone who were in a backward state of civilisation!

4. Let us imagine that such a person were to affirm that his contemporaries would live to see a coach like the "Defiance," making its trip between London and Exeter, not in thirty, but in five hours, and drawn, not by 200 blood-horses, but by a moderate sized stove and four bushels of coals!

5. Let us further imagine the same sagacious individual to predict that his contemporaries would live to see a building erected in the centre of London, in the cellars of which machinery would be provided for the fabrication of *artificial lightning*, which should be supplied *to order*, at a *fixed price*, in any quantity required, and of *any prescribed force;* that *conductors* would be carried from this building to all parts of the country, along which such *lightning* should be sent at will; that in the attics of this same building would be provided certain small instruments like barrel-organs or pianofortes; that by means of these instruments, the aforesaid lightning should, at the will and pleasure of those in charge of them, deliver messages at any part of Europe, from St. Petersburgh to Naples; and, in fine, that answers to such messages should be received instantaneously, and by like means: that in this same building offices should be provided, where any lady or gentleman might enter, at any hour, and for a few shillings send a message by *lightning* to Paris or Vienna, and by waiting for a few moments, receive an answer!

Might he not exclaim after the inspired author of the book of Job:—

"Canst thou send lightnings, that they may go, and say unto thee, Here we are"!! xxxviii., 35.

But, suppose that his foresight should further enable him to pronounce that means would be invented by which any individual in any one town or city of Europe should be enabled to take in his hand a pencil or pen, the point of which should be in any other town or city, no matter how distant, and should, with such pen or pencil, write or delineate in such distant place, such characters or designs as might please him, with as much promptitude and precision as if the paper to which these characters or designs were committed lay upon the table before him ; or that an individual pulling a string at London should ring a bell at Vienna, or holding a match at St. Petersburgh should discharge a cannon at Naples!

6. Suppose he should affirm that means would be discovered for converting charcoal into diamonds; that the light of the sun would be compelled, without the intervention of the human hand, to make a portrait or a picture, with a fidelity, truth and precision, with which the productions of the most exalted artistic skill would not bear comparison; and that this picture should be produced and completed in its most minute details in a few seconds—nay, even in the fraction of a second; that candles and lamps would be superseded by flame manufactured on a large scale in the suburbs of cities, and distributed for use in pipes, carried under the streets, and into the houses and other buildings to be illuminated; and that the precious and other metals being dissolved in liquids, would form themselves into the articles of ornament and use by a spontaneous process, and without the intervention of human labour!!

No authority however exalted, no attainments however profound, no reputation however respected, could have saved the individual rash enough to have given utterance to such predictions some forty years ago, from being regarded as labouring under intellectual derangement. Yet all these things have not only come to pass, but the contemplation of many of them has become so interwoven with our habits, that familiarity has blunted the edge of wonder.

7. Compared with all such realities, the illusions of oriental romance grow pale; fact stands higher than fiction in the scale of the marvellous ; the feats of Aladdin are tame and dull; and the slaves of the lamp yield precedence to the spirits which preside over the battery and the boiler.

8. Of all the physical agents discovered by modern scientific research, the most fertile in its subserviency to the arts of life is incontestably electricity, and of all the applications of this subtle agent, that which is transcendently the most admirable in its effects, the most astonishing in its results, and the most important in its influence upon the social relations of mankind, and upon the spread of civilisation and the diffusion of knowledge, is the Electric Telegraph. No force of habit, however long continued,

no degree of familiarity can efface the sense of wonder which the effects of this most marvellous application of science excites.

9. Being at Paris some years ago, I was engaged to share with M. Leverrier, the celebrated astronomer, and some other men of science, in the superintendence of a series of experiments to be made before committees of the Legislative Assembly and of the Institute, with the view of testing the efficiency of certain telegraphic apparatus. On that occasion operating in a room at the Ministry of the Interior appropriated to the telegraphs, into which wires proceeding from various parts of France were brought, we dictated a message, consisting of about forty words, addressed to one of the clerks at the railway station at Valenciennes, a distance of 168 miles from Paris. This message was transmitted in two minutes and a half. An interval of about five minutes elapsed, during which, as it afterwards appeared, the clerk to whom the message was addressed was sent for. At the expiration of this interval the telegraph began to express the answer, which, consisting of about thirty-five words, was delivered and written out by the agent at the desk, in our presence, in two minutes. Thus, forty words were sent 168 miles and thirty-five words returned from the same distance, in the short space of four minutes and thirty seconds.

But surprising as this was, we soon afterwards witnessed, in the same room, a still more marvellous performance.

The following experiment was prepared and performed at the suggestion and under the direction of M. Leverrier and myself:—

Two wires, extending from the room in which we operated to Lille, were united at the latter place, so as to form one continuous wire, extending to Lille and back, making a total distance of 336 miles. This, however, not being deemed sufficient for the purpose, several coils of wire wrapped with silk were obtained, measuring in their total length 746 miles, and were joined to the extremity of the wire returning from Lille, thus making one continuous wire measuring 1082 miles. A message consisting of 282 words was then transmitted from one end of the wire. A pen attached to the other end immediately began to write the message on a sheet of paper moved under it by a simple mechanism, and the entire message was written in full in the presence of the Committee, each word being spelled completely and without abridgment, in *fifty-two seconds*, being at the average rate of *five words and four-tenths per second!*

By this instrument, therefore, it is practicable to transmit intelligence to a distance of upwards of 1000 miles, at the rate of 19500 words per hour!

The instrument would, therefore, transmit to a distance of 1000 miles, in the space of an hour, the contents of about forty pages of the book now in the hands of the reader!

But it must not be imagined, because we have here produced an example of the transmission of a despatch to a distance of 1000 miles, that any augmentation of that distance could cause any delay of practical importance.

10. Although the velocity of the electric current has not been very exactly measured, it has been established beyond all doubt that it is so great that to pass from any one point on the surface of the earth to any other, it would take no more than an inappreciable fraction of a second.

11. If, therefore, the despatch had been sent to a distance of twenty thousand miles instead of one thousand, its transmission would still have been instantaneous.

Such a despatch would fly many times round the earth between the two beats of a common clock, and would be written in full at the place of its destination more rapidly than it could be repeated by word of mouth. When such statements are made, do we not feel disposed to exclaim—

> "Are such things here as we do speak about?
> Or have we eaten of the insane root,
> That makes the reason prisoner?"

In its wildest flights the most exalted imagination would not have dared, even in fiction, to give utterance to these stubborn realities. Shakspeare only ventured to make his fairy

> "Put a girdle round the earth
> In forty minutes."

To have encircled it several times in a second, would have seemed too monstrous, even for Robin Goodfellow.

The curious and intelligent reader of these pages will scarcely be content, after the statement of facts so extraordinary, to remain lost in vacant astonishment at the power of science, without seeking to be informed of the manner in which the phenomena of nature have been thus wonderfully subdued to the uses of man. A very brief exposition will be enough to render intelligible the manner in which these miracles of science are wrought.

12. The World of Science is not agreed as to the physical character of Electricity. According to the opinion of some it is a fluid infinitely lighter and more subtle than the most attenuated and impalpable gas, capable of moving through space with a velocity commensurate with its subtleness and levity. Some regard this fluid as simple. Others contend that it is compound,

consisting of two simple fluids having antagonistic properties which when in combination neutralise each other, but which recover their activity by decomposition. Others again regard it not as a specific fluid which moves through space, but as a phenomenon analogous to sound, and think that it is only a series of undulations or vibrations that are propagated through a highly elastic medium which produce the various electrical effects just as the pulsations of the atmosphere produce all the effects of sound.

13. Happily these difficult discussions are not necessary to the clear comprehension of the laws which govern the phenomena, upon which electric telegraphy depends. It will nevertheless for the purposes of explanation be convenient to use a system of language, which implies the existence of a certain fluid which we shall call the electric fluid, capable of moving over certain bodies, and being obstructed or altogether stopped by others, and which by its presence or proximity produces certain definite effects, mechanical and chemical.

14. Whether the electric agency be or be not a material fluid for our present purpose is unimportant. It is enough that it comports itself as such, and that the properties or effects which we shall impute to it are such only as it is ascertained by observation and experiment to possess or produce.

15. However various the forms may be which invention has conferred upon electric telegraphs, their efficiency in all cases depends on our power to produce at will the following effects:—

1st. To produce or develop the electric fluid in any desired quantity, and of the necessary quality.

2nd. To transmit it with celerity to any required distance, without injuriously dissipating it.

3rd. To cause it upon its arrival at any assigned point to produce some sensible effects, which may serve the purpose of written or printed characters.

16. The electric fluid is deposited in a latent state in unlimited quantity in the earth, the waters, the atmosphere, and in all bodies upon the earth, whether solid, liquid, or gaseous. It is disengaged and rendered active by various causes, natural and artificial. The mutual friction of bodies, contact and pressure, the contiguity or contact of bodies having different temperatures, the chemical action of bodies one upon another, the action of magnetic bodies on each other, and on bodies susceptible of magnetism, are severally causes of the development of the electric fluid in greater or less quantity.

Founded upon these phenomena, various apparatus have been contrived, by means of which the electric fluid may be evolved and collected in any desired quantity, and with any required intensity. Among these, that which has proved to be the most efficient for telegraphic purposes is the GALVANIC or VOLTAIC BATTERY.

17. This apparatus is to the electric telegraph what the boiler is to the steam-engine. It is the generator of the fluid by which the action of the telegraphic machine is produced and maintained. It supplies the fluid in any required quantity and of any desired intensity. As the boiler is supplied with expedients by which within practical limits the quantity and pressure of the steam may be varied, according to the exigences of the work to which the engine is applied, so the voltaic battery is provided with expedients by which the quantity and intensity of the electric fluid it evolves can be varied according to the distance to which the intelligence is to be transmitted; and the form, whether visible, oral, written, or printed, in which it is required to be delivered at the place of its destination.

18. The electric fluid being thus produced in sufficient quantity, it is necessary to provide adequate means of transmitting it to a distance without exposing it to any cause of injurious dissipation or waste.

If tubes or pipes could be constructed with sufficient facility and cheapness, through which the subtle fluid could flow, and which would be capable of confining it during its transit, this object would be attained. As the galvanic battery is analogous to the boiler, such tubes would be analogous in their form and functions to the steam-pipe of a steam-engine.

19. The construction of such means of transmission has been accomplished by means of the well-known property of the electric fluid, in virtue of which it is capable of passing freely over a certain class of bodies called CONDUCTORS, while its movement is arrested by another class of bodies called NON-CONDUCTORS or INSULATORS.

The most conspicuous examples of the former class are the metals; the most remarkable of the latter being resins, wax, glass, porcelain, silk, cotton, dry air, &c.

20. Now if a rod or wire of metal be coated with wax, or wrapped with silk, the electric fluid will pass freely along the metal, in virtue of its character of a conductor; and its escape from the metal laterally will be prevented by the coating, in virtue of its character of an insulator.

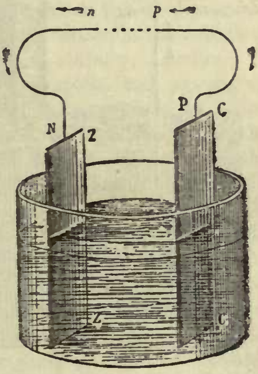
The insulator in such cases is, so far as relates to the electricity, a real tube, inasmuch as the electric fluid passes through the metal included by the coating, in exactly the same manner as water or gas passes through the pipes which conduct it; with this difference, however, that the electric fluid moves along the wire more freely, in an almost infinite proportion, than does either water or gas in the tubes which conduct them.

If, then, a wire, coated with a non-conducting substance, capable of resisting the vicissitudes of weather, were extended between any two distant points, one end of it being attached to one of the extremities of a galvanic battery, a stream of electricity would pass along the wire—*provided the other end of the wire were connected by a conductor with the other extremity of the battery.*

21. How the fluid transmitted to a distant station is made to produce the effects by which messages are expressed will be explained hereafter, meanwhile it will be necessary first to explain the form and principle of the voltaic batteries used for telegraphic operations, and secondly the expedients by which the current is transmitted and suspended, and turned in one or another direction at the will of the operator at the station from which despatches are transmitted.

To comprehend the principle of the voltaic battery, let us suppose that two strips cut, one Z Z from a sheet of zinc, and the other C C (fig. 1) from a sheet of copper, are immersed without touching each other in a vessel containing water slightly acidulated. To the upper edges P and N of the strips let two pieces of wire P *p* and N *n*, be soldered. In this state of the apparatus no development of the electric fluid will be manifested; but if the ends *p* and *n* of the wires be brought into contact, an electric current will set in, running on the wires from P, the point where the wire is soldered to the copper C C, to N, the point where the other wire is soldered to the zinc Z Z. This current will continue to flow so long as the ends *p* and *n* of the wires are kept in mutual contact, and no longer. The moment the ends *p* and *n* are separated, the current ceases.

Fig. 1.




22. The commencement of the current upon the contact of the wires, and its cessation upon their separation, are absolutely *instantaneous;* so much so, that if the ends *p* and *n* were brought into contact and separated a hundred times in a second, the flow and suspension of the current being simultaneous with the

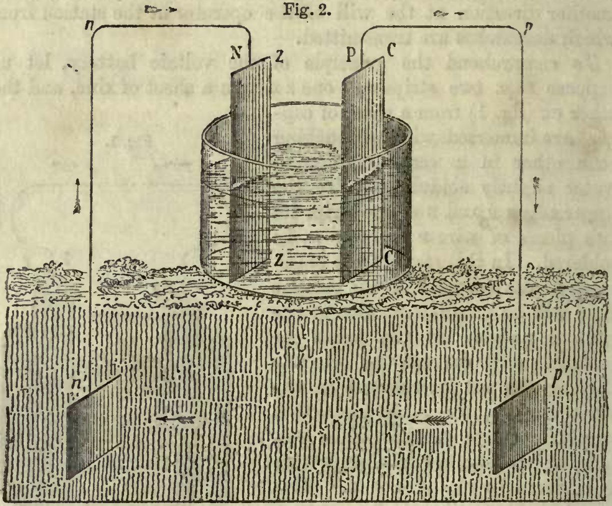
contacts and separations, would also take place a hundred times in a second.

The existence of the current established in this case is independent of the length of the wires P $p$ and N $n$. Whether their length be 10 feet, 10 miles, or 100 miles, the current will still flow upon them when their extremities $p$ and $n$ are brought into contact. The only difference will be, that the intensity of the current will be less in the same proportion as the length of the wires is augmented.

23. There is another condition of great importance, whether regarded theoretically or practically, on which the current will be established and maintained.

Instead of bringing the wires P $p$ and N $n$ into contact, let them be continued downwards, as represented in fig. 2, and connected with two plates of metal $p'$ and $n'$, buried in the earth, or

Fig. 2.




with masses of metal or other good conducting body of any form whatever thus buried. In that case the current will be established as before, flowing along the wire soldered to the copper from P to $p'$ and along that soldered to the zinc from $n'$ to N.

Thus, in both cases the current starts from the copper, and, following the course of the wires, returns to the zinc. In the former case, however, it is continuous; but in the latter it is apparently broken, terminating at $p'$, and recommencing at $n'$.

24. In the electric theories it is assumed that the course of the current, when it exists at all, must in all cases be continuous and unbroken from P to N, as it is in fact under the conditions represented in fig. 1, when the ends $p$ and $n$ are in contact. It is therefore assumed that in the case represented in fig. 2, the stratum of the earth which is interposed between $p'$ and $n'$ plays the part of a metallic wire joining these points, and that the current which arrives by the wire P $p p'$ at $p'$ flows through the earth, as indicated by the arrow, to $n'$, from whence it flows along the wire $n' n$ N to N.

It is found also in this case that the existence of the current is independent of the lengths of the wires, which do not affect it otherwise than by diminishing its intensity. Whether the wires are 10 feet, 10 miles, or 100 miles in length, the current still flows from P to $p'$ and returns from $n'$ to N.

25. Thus, admitting the generally acknowledged principle that the stratum of the earth intervening between $p'$ and $n'$ plays the part of a conducting wire, uniting the ends $p'$ and $n'$ of the wires buried, it will follow that the current at $p'$, though separated, as it may be, by a distance of several hundred miles from the point $n'$ of its return to N, finds its way nevertheless through the earth unerringly and instantaneously to that point.

Of all the miracles of science, surely this is the most marvellous. A stream of electric fluid has its source in the cellars of the Central Electric Telegraphic Office, Lothbury, London. It flows under the streets of the great metropolis, and, passing on wires suspended over a zigzag series of railways, reaches Edinburgh, where it dips into the earth, and diffuses itself upon the buried plate. From that it takes flight through the crust of the earth, and *finds its own way* back to the cellars at Lothbury!!!

Instead of burying plates of metal, it would be sufficient to connect the wires at each end with the gas or water pipes, which, being conductors, would equally convey the fluid to the earth; and in this case, every telegraphic despatch which flies to Edinburgh along the wires which border the railways, would fly back, rushing to the gas-pipes which illuminate Edinburgh, from them through the crust of the earth to the gas-pipes which illuminate London, and from them home to the batteries in the cellars at Lothbury!

26. To derive all the necessary instruction from what has been explained above, it will be necessary to distinguish what is essential from what is merely optional, and which admits of modification or change without affecting the result.

27. It will be seen that the electric fluid is evolved by the combination of three bodies, the zinc, the copper, and the acidu-

lated solution in which they are immersed. The production of the current depends on the chemical action of the solution on the zinc. That metal being very susceptible of oxydation, decomposes the water which is in contact with it. One constituent of the water combining with the zinc, produces a compound called the oxyde of zinc, and this oxyde entering again into combination with the acid which the water holds in solution, forms a soluble salt. If the acid, for example, be sulphuric acid, this salt will be the sulphate of the oxyde of zinc, and as fast as it is produced it will be dissolved in the water in which the slips of metal are immersed.

Meanwhile, the copper not being as susceptible of chemical action as the zinc, remains comparatively unaffected by the solution; but the hydrogen evolved in the decomposition of the water collects upon its surface, after which it rises and escapes in bubbles at the surface of the solution.

It is to this chemical action upon the zinc that the production of the electric current is due. If a like action had taken place in the same degree on the copper, a similar and equally intense electric current would be produced in the opposite direction; and in that case the two currents would neutralise each other, and no electric effect would ensue.

From this it will be seen that the efficacy of the combination must be ascribed to the fact, that one of the two metals immersed in the solution is more oxydable than the other, and that the energy of the effect and the intensity of the current will be so much the greater as the susceptibility of oxydation of the one metal exceeds that of the other.

28. It appears, therefore, that the principle may be generalised, and that electricity will be developed, and a current produced by any two metals similarly placed, which are oxydable in different degrees.

Zinc being one of the most oxydable metals, and being also sufficiently cheap and abundant, is generally used by preference for voltaic combinations. Silver, gold, and platinum are severally less susceptible of oxydation, and of chemical action generally, than copper, and would therefore answer voltaic purposes better, but are excluded by their greater cost, and by the fact that copper is found sufficient for all practical purposes.

29. It is not, however, absolutely necessary that the inoxydable element C C of the combination should be a metal at all. It is only necessary that it be a good conductor of electricity. In certain voltaic combinations, charcoal properly solidified has therefore been substituted for copper, the solution being such as would produce a strong chemical action on copper.

30. In the above illustration, we have supposed that the

metallic elements of the combination are thin rectangular slips cut from sheet metal. The form, however, is in no manner essential to the production of the electric current. So long as the magnitude of the surfaces exposed to contact with the solution is the same, the current will have the same force. The pieces of metal may therefore have the form here supposed of thin rectangular plates, or they may be formed, as is often found convenient, into hollow cylinders, that of the copper being so much less in diameter than that of the zinc, that it is capable of being placed within it without mutual contact.

The simple arrangement first adopted by Volta consisted of two equal discs of metal, one of zinc, and the other of copper or silver, with a disc of cloth or bibulous card, soaked in an acid or saline solution, between them. These were usually laid, with their surfaces horizontal, one upon the other.

The late Dr. Wollaston proposed an arrangement, in which the copper plate was bent into two parallel plates, a space between them being left for the insertion of the zinc plate, the contact of the plates being prevented by the interposition of bits of cork or other non-conductor. The system thus combined was immersed in dilute acid, contained in a porcelain vessel.

Dr. Hare of Philadelphia contrived a voltaic arrangement, consisting of two metallic plates, one of zinc and the other of copper, of equal length, rolled together in the form of a spiral, a space of a quarter of an inch being left between them. They are maintained parallel without touching, by means of a wooden cross at top and bottom, in which notches are provided at proper distances, into which the plates are inserted, the two crosses having a common axis. This combination is let into a glass or porcelain cylindrical vessel of corresponding magnitude, containing the exciting liquid.

This arrangement has the great advantage of providing a very considerable electro-motive surface with a very small volume.

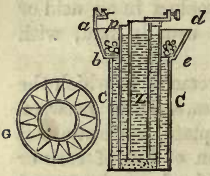
The exciting liquid recommended for these batteries when great power is desired, is a solution in water of $2\frac{1}{4}$ per cent. of sulphuric, and 2 per cent. of nitric acid. A less intense but more durable action may be obtained by a solution of common salt, or of 3 to 5 per cent. of sulphuric acid only.

31. It is not essential that the water in which the metals are immersed be acidulated, as we have supposed, by sulphuric acid. Any acid which will promote the oxydation of the zinc without affecting the copper will answer. Nor is it indeed necessary that any acid whatever be used. A saline solution is often found more convenient. Thus common salt dissolved in the water will produce the desired effect.

Of the various voltaic combinations which have been applied in scientific researches, four only have been found available to any considerable extent in the working of electric telegraphs, the zinc and copper plate combination described above, Daniel's constant battery, Grove's battery, Bunsen's modification of it, and the magneto-electric apparatus.

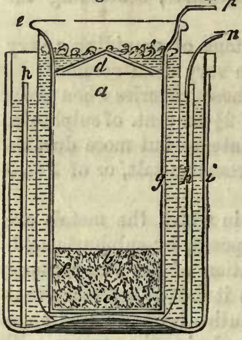
32. Daniel's combination, which is extensively used in working the telegraphs on the continent, consists of a copper cylindrical vessel C C, fig. 3, widening near the top *a d*. In this is placed a cylindrical vessel of unglazed porcelain *p*. In this latter is placed the hollow cylinder of zinc Z, already described. The space between the copper and porcelain vessels is filled with a saturated solution of the sulphate of copper, which is maintained in a state of saturation by crystals of the salt placed in the wide cup *a b c d*, in the bottom of which is a grating composed of wire carried in a zigzag direction between two concentric rings, as represented in plan at G. The vessel *p*, containing the zinc, is filled with a solution of sulphuric acid, containing from 10 to 25 per cent. of acid when greater electro-motive power is required, and from 1 to 4 per cent. when more moderate action is sufficient.

Fig. 3.




33. The following modification of Daniel's system was adopted by M. Pouillet in his experimental researches, and is the form and arrangement used in France for the telegraphs. A hollow cylinder *a*, fig. 4, of thin copper, is ballasted with sand *b*, having a flat bottom *c*, and a conical top *d*. Above this cone the sides of the copper cylinders are continued, and terminate in a flange *e*. Between this flange and the base of the cone, and near the base, is a ring of holes. This copper vessel is placed in a bladder which fits it loosely like a glove, and is tied round the neck under the flange *e*. The saturated solution of the sulphate of copper is poured into the cup above the cone, and, flowing through the ring of holes, fills the space between the bladder and the copper vessel. It is maintained in its state of saturation by crystals of the salt deposited in the cup.

Fig. 4.




This copper vessel is then immersed in a vessel of glazed porcelain *i*, containing a solution of the sulphate of zinc or the chloride of sodium (common salt). A hollow cylinder of zinc *h*, split down the side so as to be capable of being enlarged, or contracted at pleasure, is immersed in this solution surrounding the bladder. The poles are indicated by the conductors *p* and *n*, the positive proceeding from the copper, and the negative from the zinc.

M. Pouillet states that the action of this apparatus is sustained without sensible variation for entire days, provided the cup above the cone *d* is kept supplied with the salt, so as to maintain the solution in the saturated state.

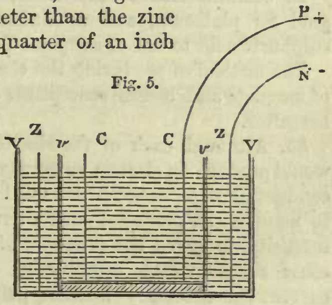
In the batteries used for the telegraphs on the French railways, the liquid in which the zinc cylinder is immersed is pure water, and this is found to answer in a very satisfactory manner.

The current flows from the copper cylinder and returns as usual to the zinc.

34. Grove's battery consists of two liquids, sulphuric and nitric acids, and two metals, zinc and platinum, arranged in the following manner:—

A hollow cylinder of zinc Z Z, fig. 5, open at both ends as already described, is placed in a vessel of glazed porcelain V V. Within this is placed a cylindrical vessel *v v*, of unglazed porcelain, a little less in diameter than the zinc Z Z, so that a space of about a quarter of an inch may separate their surfaces. In this vessel *v v*, is inserted a cylinder C C of platinum, open at the ends, and a little less than *v v*, so that their surfaces may be about a quarter of an inch asunder. Dilute sulphuric acid is then poured into the vessel V V, and concentrated nitric acid into *v v*; P proceeding from the platinum will then be the positive, and N proceeding from the zinc the negative pole.

Fig. 5.




Bunsen contrived a battery which has taken his name, and which, while it retains all the efficiency of Grove's, can be constructed at much less expense, the platinum element being replaced by the cheaper material of charcoal.

In the vessel *v v* is inserted, instead of a hollow cylinder of platinum, a solid cylindrical rod of charcoal, made from the residuum taken from the retorts of gas-works. A strong porous mass is produced by repeatedly baking the pulverised coke, to which the required form is easily imparted. Dilute sulphuric acid is then poured into the vessel V V, and concentrated nitric acid into *v v*. The electric fluid issues from a wire connected with the charcoal, and returns by one connected with the zinc.

Messrs. Deleuil and Son, of Paris, have fabricated batteries on this principle with great success. I have one at present in use consisting of fifty pairs of zinc and carbon cylinders, the zinc being $2\frac{1}{2}$ inches diameter, and 8 inches high, which performs very satisfactorily.

The chief advantage of Daniel's system is that from which it takes its name, its *constancy*. Its power, however, in its most efficient state, is greatly inferior to that of the carbon or platinum systems of Bunsen and Grove. A serious practical inconvenience, however, attends all batteries in which concentrated nitric acid is used, owing to the diffusion of nitrous vapour, and the injury to which the parties working them are exposed by respiring it. In my own experiments with Bunsen's batteries the assistants have been often severely affected.

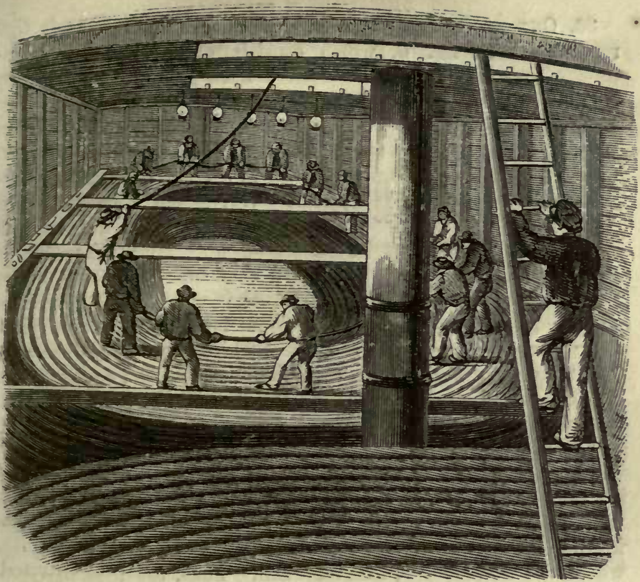
In the use of the platinum battery of Grove, the nuisance produced by the evolution of nitrous vapour is sometimes mitigated by enclosing the cells in a box, from the lid of which a tube proceeds which conducts these vapours out of the room.

In combinations of this kind, Dr. O'Shaugnessy substituted gold for platinum, and a mixture of two parts by weight of sulphuric acid to one of saltpetre for nitric acid.

The method of producing the electric fluid by the mutual action of magnets and bodies susceptible of magnetism will be described hereafter.

35. Although each of the simple combinations described above would produce an electric current, which, being transmitted upon a conducting wire, would be attended with effects sufficiently distinct to manifest its presence, such a current would be too feeble in its intensity to serve the purposes of a telegraphic line; and as no other simple voltaic combination yet discovered would give to a current the necessary intensity, the object has been attained by placing in connection a series of such combinations, in such a manner that the currents produced by each of them being transmitted in the same direction, on the same conducting wire, a current having an intensity due to such combination may be obtained.

Such a series of simple voltaic combinations, so united, is called a VOLTAIC BATTERY.



CABLE IN THE HOLD OF THE VESSEL.

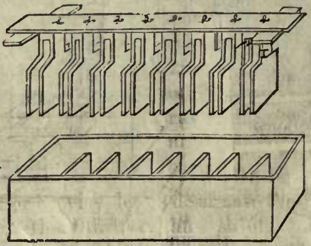
# THE ELECTRIC TELEGRAPH.

## CHAPTER II.

36. Common plate battery.—37. Combination of currents.—38. Loss of intensity by imperfect conduction.—39. Cylindrical batteries.—40. Pairs, elements, and poles defined.—41. Origin of term *voltaic pile.*—42. Use of sand in charging batteries.—43. To vary intensity of current.—44. Batteries used for English telegraphs.—45. Amalgamating the zinc plates.—46. The line-wires, material and thickness.—47. Objection to iron wires.—48. Manner of carrying wires on posts —49. Good insulation.—50. Expedients for obtaining it.—51. Forms of insulating supports.—52. Dimensions and preparations of the posts.—53. Forms of support used in England.—54. Winding posts.—55. Supports in France.—56. In America.—57. In Germany.—58. Wire insulated by superficial oxydation.—59. Leakage of the electric fluid by the conduction of the atmosphere.—60. Effects of atmospheric electricity on the wires.—61. Lightning conductors.—62. Those of Messrs. Walker and Breguet.—63. Conducting current into stations.—64. Underground wires.—65. Methods of insulating them.—66. Testing posts.

36. One of the most simple forms of voltaic battery is that represented in fig. 6, which consists of a glazed earthenware trough, divided by partitions into a series of parallel cells, and a series of zinc and copper plates, A′ B′, of shape and magnitude corresponding with the cells, attached to a wooden rod, each copper plate being connected at the top, under the wood, by a band of metal, with the zinc plate which immediately succeeds it in the series. For brevity, let us designate the first copper plate, $c_1$, the second $c_2$, the third, $c_3$, and so on, proceeding from A′ towards B′, and let the first zinc plate, which is connected with $c_1$ by a metal band, be called $z_2$, the next, which is similarly connected with $c_2$, be called $z_3$, and so on from A′ towards B′. Now, the intervals between the plates being so arranged as to correspond with the width of the cells, the series of plates may be let down into the cells so that a partition shall separate every pair of plates which are connected by a metal band. Thus, the first partition will pass between $c_1$ and $z_2$, the second between $c_2$ and $z_3$, the third between $c_3$ and $z_4$, and so on. It appears, therefore, that the first cell proceeding from A towards B will contain only the copper plate $c_1$, the second will contain $c_2$ and $z_2$, the third, $c_3$ and $z_3$, and so on, the last cell at the extremity B of the series containing only the last zinc plate, which we shall call $z_n$.

Fig. 6.

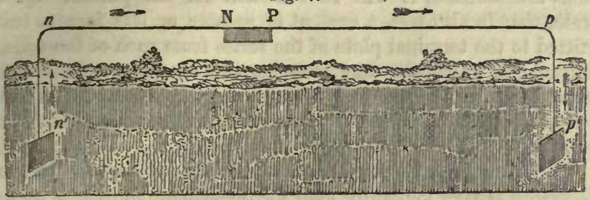



Now, it is evident that as the arrangement thus stands, the first and last cells of the series would differ from the intermediate ones, inasmuch as, while each of the latter contains a pair of plates, each of the former contains only a single plate, the first copper $c_1$ and the last zinc $z_n$. To complete the arrangement, therefore, it will be necessary to place a zinc plate, which we shall call $z_1$, in the first cell to the left of $c_1$, and so as not to be in contact with it, and in like manner a copper plate, which we shall call $c_n$, in the last cell B to the right of $z_n$, and so as not to be in contact with it. Let wires be soldered to the upper edges of these terminal plates $z_1$ and $c_n$, and let them be carried to any desired distances, but finally connected with plates, or any other masses of metal, buried in the ground at $n'$ and $p'$, fig. 7.

These dispositions being made, let us suppose the cells to be filled with a weak acid solution, such as has been already described, but so that the liquid in one cell may not overflow into the next.

A current of electricity will now be established along the wire passing as indicated by the arrows, from the last copper plate at P,

Fig. 7.




to the earth at $p'$, and returning by $n'$ to the first zinc plate $z_1$, at N.

This current is produced by the combined voltaic action of all the pairs of plates contained in the cells of the trough.

37. The current produced by the combination $z_1$ $c_1$, in the first cell, will flow from the plate $c_1$ by the band of metal to the plate $z_2$, in the second cell. It will follow this course because of the conducting power of the metals, and the insulating power of the wood and earthenware, which prevents its escape. From the plate $z_2$ it will pass through the acidulated water to the plate $c_2$, for although this water has not a conducting power equal to that of metal, it has nevertheless sufficient to continue the current to $c_2$. From $c_2$ it will pass by the band of metal to $z_3$, and from that through the liquid in the third cell to $c_3$, and from that by the metal to $z_3$, and so on until it arrives at the last plate $c_n$ of the series, from which it will pass, by the conducting wire, from P to $p'$.

It is evident, therefore, that the current produced by the voltaic combination in the first cell must pass successively through the plates and liquid in all the cells before it can arrive at P.

In the same manner it may be shown that the current produced in the second cell containing $z_2$ and $c_2$ must pass through all the succeeding cells before it can reach P, and so of all the others.

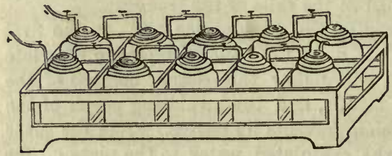
38. Now, if the metals and liquid were perfect conductors, each of these currents would arrive at P with undiminished force, and then the current upon the wire P $p'$ would be as many times more intense than a current produced by a single voltaic combination as there are cells. But this is not so. The metals copper and zinc, though good conductors, are not perfect ones, and the acidulated water is a very imperfect one. The consequence is, that the currents severally produced in each of the cells, suffer a considerable loss of force before they arrive at the conducting wire P$p'$; and mathematical formulæ, based on theoretical principles and practical data, have been contrived to express in each case the effects of this

diminution of force due to the imperfect conducting power, or the *resistance*, as it has been called, of the elements of the battery.

Without going into the reasoning upon which these investigations are founded, it will be sufficient for our present object to state, that in all cases, a current of greater or less force is transmitted to the terminal plate of the series from each of the cells, no matter how numerous they may be, and in some cases batteries have been constructed and brought into operation, in scientific researches, which consisted of as many as two thousand pairs of plates.

39. To simplify the explanation, as well as because the form described is very generally used for telegraphic purposes, we have here selected the plate battery to illustrate the general principle upon which all voltaic combinations are founded. In fig. 8 is represented the disposition of the cylinders in a battery formed on the principles of Daniel or Grove, where the metallic connection of each copper or charcoal element of one pair, with the zinc element of the succeeding pair, is represented by a rectangular metallic bar or wire.

Fig. 8.



40. Each combination of two metals, or of one metal and charcoal, which enters into the composition of a battery, is usually called a PAIR, and sometimes an ELEMENT. Thus, a battery is said to consist of so many PAIRS, or so many ELEMENTS.

The end of the battery from which the current issues is called its POSITIVE POLE, and that to which it returns is called its NEGATIVE POLE. Thus, in the batteries explained above, P is the positive, and N the negative pole.

Since in the most usual elements, zinc and copper, the current issues from the last copper plate, and returns to the first zinc plate, the positive pole is sometimes called the COPPER POLE, and the negative the ZINC POLE.

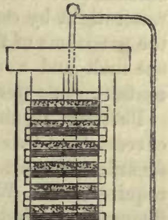
41. The voltaic battery is sometimes called the VOLTAIC PILE. This term had its origin from the forms given to the first voltaic combination by its illustrious inventor.

The first pile constructed by Volta was formed as follows:—A disc of zinc was laid upon a plate of glass. Upon it was laid an equal disc of cloth or pasteboard, soaked in acidulated water. Upon this was laid an equal disc of copper. Upon the copper were laid, in the same order, three discs of zinc, wet cloth, and copper, and the same superposition of the same combinations of zinc, cloth, and copper, was continued until the pile was completed. The highest disc (of copper) was then the positive, and the lowest disc (of zinc) the negative pole, according to the principles already explained.

It was usual to keep the discs in their places by confining them between rods of glass.

Such a pile, with conducting wires connected with its poles, is represented in fig. 9.

Fig. 9.



42. As the batteries used on telegraphic lines are liable to frequent removal from place to place while charged with the acidulated water, or other exciting liquid, it has been found desirable to contrive means to prevent such liquid from being spilled, or thrown from cell to cell. This has been perfectly accomplished by the simple expedient of filling the cells with silicious sand, which is kept saturated with the exciting liquid so long as the battery is in operation.

43. It is often necessary, in telegraphic operations, to vary the intensity of the current. This is accomplished, within certain limits, without changing the battery, in the following manner:—

If it be desired to give the full force of the battery to the current, the wires are attached to the terminal plates, so that the entire battery is between them. But if any less intensity is desired, the wires, or one of them, is attached to intermediate plates, so that they shall include between them a part only of the battery. The part included between them is alone active in producing the current, all the elements which are outside the wires being passive. The battery, in effect, is converted into one of fewer elements.

Provisions are made, which will be explained hereafter, by which the operator can, by a touch of the hand, thus vary the force of the battery.

44. The batteries generally used for the English telegraphs are those described in (36). They are usually charged with sand, wetted with water mixed with sulphuric acid, in the proportion of about one part of strong acid to fifteen of water. A more intense current could be produced by using a stronger solution, but it is found preferable to augment its intensity by increasing the number of plates in the battery. The dimensions

of the plates are generally four to five inches wide, and three to four inches deep. The thickness of the zinc plates is something less than a quarter of an inch. The cells are filled with sand to within an inch of the top, and the parts of the plates above the sand are varnished as a protection against corrosion, and to keep them clean. In general, the troughs are made either of glazed earthenware or some compact wood, such as oak, or teak, made water-tight by cement or marine glue. When the trough is wood the partitions of the cells are slate, the width of each cell being one inch and a quarter to one inch and a half. The troughs contain, some twenty-four, and some twelve cells.

Batteries of this sort, consisting of twenty-four cells, give a current of sufficient force for a line of wire of 15 miles. For 50 miles, 48 cells, and for 75 miles, three troughs of 24 cells are required. Mr. Walker considers that these batteries give superfluous force, but that it is necessary to provide against the contingency of leakage by accidental defects of insulation.

45. The durability of these batteries is increased by amalgamating the zinc plates. This is effected by first washing them in acidulated water, and then immersing them in a bath of mercury for one or two minutes. The mercury will combine with the zinc and form a superficial coating of the amalgam of zinc. When they are worn by use, they may be restored, by scouring them, and submitting them to the same process, and this may be continued until the zinc become too thin to hold together.

Mr. Walker states that new batteries, when carefully put together, will, with care, do duty for six or eight months, when the work is not very heavy; and by washing the sand out with a flow of water, and refilling them, they have frequently remained on duty ten or twelve months, or even more, without having been sent in for re-amalgamation.*

46. Having explained, generally, the manner in which the electric current is produced and maintained, I shall now proceed to explain the various expedients by which it is conducted from station to station, along the telegraphic line, and by which injurious waste by leakage or drainage is prevented or diminished.

The conducting wires used for telegraphic lines are of iron, usually the sixth of an inch in diameter. On all European lines they are submitted to a process called galvanisation, being passed through a bath of liquid zinc, by which they become coated with that metal. This zinc surface being easily oxydable, is soon, by the action of air and moisture, converted into the oxyde of zinc, which, being insoluble by water, remains upon the wire, and protects the iron from all corrosion.

* El. Tel. Manip., p. 8.

When a great length of wire is to be stretched between two distant points without intermediate support, steel wire is often preferred to iron, in consequence of its greater strength and tenacity.

Copper being a better conductor of electricity than iron, as well as being less susceptible of oxydation, would on these accounts be more eligible for telegraphic purposes. Its higher price, and the possibility of compensation for the inferior conducting power of iron, by using greater battery power, has rendered it preferable to use that metal.

47. Mr. Highton, the inventor of some important improvements in telegraphic apparatus, affirms that, when galvanised iron wires pass through large towns where great quantities of coal are burnt, the sulphureous acid gas resulting from such combustion acting upon the oxyde of zinc which coats the conducting wire, converts it into a sulphate of zinc, which being soluble in water, is immediately dissolved by rain, leaving the iron unprotected. The wire consequently soon rusts, and is corroded. Mr. Highton says, that in some cases he has found his telegraph wires reduced by this cause to the thinness of a common sewing needle in less than two years.

The wires used on the American lines are of iron, similar to the European, but are not galvanised. They soon become coated with their own oxyde. A pair of galvanised wires have been placed between New York and Boston, and I have been informed by Mr. Shaffner, the secretary of the American Telegraph Confederation, that at certain times during the winter, it has been found that they were unable to work the telegraph with these wires, while its operation with the wires not galvanised, was uninterrupted. Mr. Shaffner also states that several anomalous circumstances have been manifested upon some extensive lines of wire erected on the vast prairies of Missouri. Thus, in the months of July and August, it is found that the telegraph cannot be worked from two to six in the afternoon, being the hottest hours of the day. These circumstances are ascribed to some unexplained atmospheric effects.

48. The manner in which the conducting wires are carried from station to station is well known. Every railway traveller is familiar with the lines of wire extended along the side of the railways, which, when numerous, have been not unaptly compared to the series of lines on which the notes of music are written, and which are the metallic wires on which invisible messages are flying continually with a speed that surpasses imagination. These are suspended on posts, erected at intervals of about sixty yards, being at the rate of thirty to a mile. They therefore supply incidentally a convenient means by which a passenger can ascertain the speed

of the train in which he travels. If he count the number of telegraph posts which pass his eye in two minutes, that number will express in miles per hour the speed of the train.

49. Since the current of electricity which flows along the wire has always a tendency to pass by the shortest route possible to the ground, it is evident that the supports of the wires upon these posts ought to possess, in the highest attainable degree, the property of insulation; for even though the entire stream of electrical fluid might not make its escape at any one support, yet if a little escaped at one and a little at another, the current would, in a long line, be soon so drained that what would remain would be insufficient to produce those effects on which the efficiency of the telegraph depends. Great precautions have therefore been taken, and much scientific ingenuity has been expended in contriving supports which shall possess, in the highest attainable degree, the property of insulation.

50. To each of these posts or poles are attached as many tubes or rollers, or other forms of support, in porcelain or glass, as there are wires to be supported. Each wire passes through a tube, or is supported on a roller; and the material of the tubes or rollers being among the most perfect of the class of non-conducting substances, the escape of the electricity at the points of contact is impeded.

Notwithstanding various precautions of this kind, a considerable escape of electricity still takes place in wet weather. The coat of moisture which collects on the wire, its support, and the post, being a conductor, carries away more or less of the fluid. Consequently, more powerful batteries are necessary to give effect to the telegraph in wet than in dry weather.

In England, and on the Continent, the material hitherto used for the supports of the wires is principally a sort of earthen or stone ware. In the United States it is generally glass.

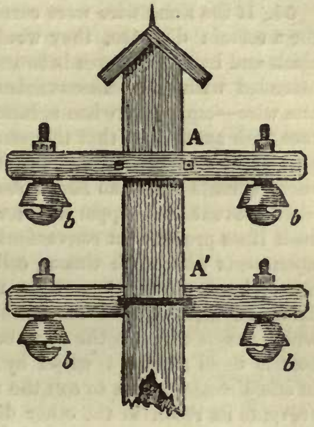
51. The forms of these insulating supports are various. Tubes, rings, collars, and double cones, are severally used. The material used most commonly in England, a sort of brown stoneware, has the advantage, besides being a good insulator, of throwing off wet, as water falls from a duck's wing, leaving the surface dry. A pitcher of this ware, plunged in water, scarcely retains any moisture upon it.

52. The posts vary generally from 15 to 30 feet in height, the lowest wire being about ten feet above the ground, except in cases where greater height is required to allow vehicles to pass under it, as when the wires cross a common road, or pass from one side of the railway to the other. The poles are about 6 inches square at the top, and increase to 8 inches at the bottom. In some cases they are impregnated with certain chemical solutions, to preserve them from rotting, and are generally painted, the parts

which are in the ground being charred and tarred. The manner of treatment, however, varies in different countries.

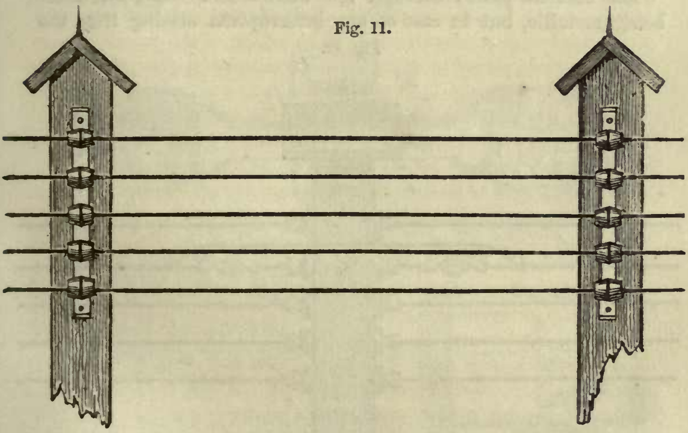
53. In figs. 10 and 11 are represented different forms of supports used in England. To cross-pieces of wood, A A′, bolted upon the post (fig. 10), are attached balls, *b*, of stone-ware, as described above, in which grooves or slits are formed to receive and support the wires. These supports are protected from rain and from the deposition of dew by hoods of zinc-coated iron placed over them. Glass being so much better an insulator, balls of that material are recently being substituted for the stoneware.

Fig. 10.




Another form of support, sheltered by a sort of sloping roof, is represented in fig. 11. On the front of the post is a wooden arm to which a series of stone-ware rings are

Fig. 11.



attached, through which the wires pass. These rings have the form of two truncated cones placed with their larger bases in contact.

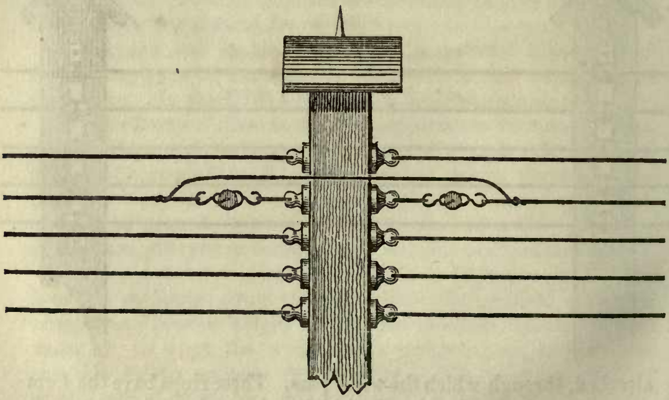
It is usual, where the wires are numerous, as on some of the lines near London, to attach these supports both to the front and back of the post. So many as thirteen of these supports may be seen upon some of the posts of the North-Western line near London. The wires supported on some of these are continued to Liverpool and Manchester, and some even to Glasgow.

54. If the same wire were carried over a succession of supports for a certain distance, they would after a certain time become slack and hang in curves between post and post. This would be attended with great inconvenience and confusion, inasmuch as one wire—especially when agitated by wind—would come in contact with another, so that the currents running along them would pass from one to another, and the proper signals conveyed by such currents would no longer reach their destination.

To prevent this, apparatus for tightening the wire are on all such lines provided at convenient distances, such as half-a-mile, upon posts which are thence called *winding posts.* These posts are of larger dimensions than the ordinary posts. A grooved drum, on which the wire is wound, is attached to them by a bolt, which passes through the post, but clear of the wood. Upon this bolt is fixed a ratchet wheel by which the drum may be turned in one direction, so as to coil the wire upon it, with a catch which prevents its recoil in the other direction, and therefore maintains the tension of the wire. The bolt is kept from contact with the post by passing through a stoneware collar.

The current passes through the winder and the bolt, these being metallic, but in case of any interruption arising from the

Fig. 12.



oxydation of their surfaces a supplemental piece of conducting wire is provided, which connects the main wires at points taken above and below the winding post, as represented in fig. 12.

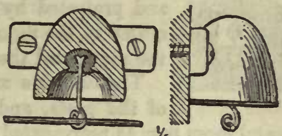
55. In France the posts are from twenty to thirty feet high, placed at distances varying from sixty to seventy yards asunder, and sunk to a depth of from three to seven feet in the ground. They are impregnated with sulphate of copper to preserve them from rotting by damp.

The conducting wire rests in an iron hook, which is fastened by sulphur into the highest part of the cavity of an inverted bell, formed of porcelain, from which two ears project, which are screwed to the post.

A section of this apparatus is given in fig. 13, and a side view in fig. 14, the figures being one-fifth of the actual magnitude.

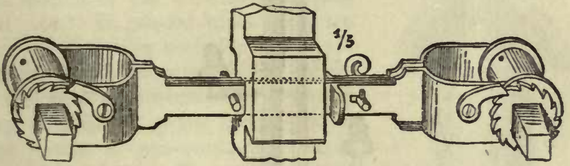
The winding posts are placed at distances of a kilometre (six-tenths of a mile). The apparatus used for tightening the wire consists of two drums or rollers, each carrying on its axis a ratchet wheel with a catch. These drums are mounted on iron forks formed at the ends of an iron bar, which is passed through an opening in a porcelain support, and secured in its position by pins, the porcelain support being attached to the post by screws passing through ears projecting from it.

Figs. 13, 14.




A front view of this winding apparatus is given fig. 15; a side view of the porcelain support showing the opening through which the iron bar is passed, and the screws by which it is attached to the post, is given in fig. 16.

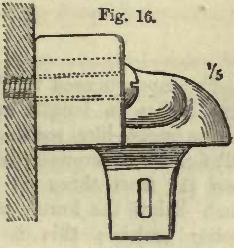
Fig. 15.




These figures are one-fifth of the real magnitude of the apparatus.

The conducting wires used in France are similar to those used on the English lines.

Fig. 16.

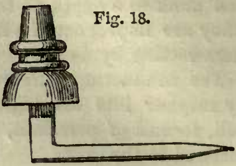



56. The insulating supports of the wires used on the American lines are very various in form.

The supports upon the principal Morse lines consist of a glass knob, fig. 17, upon which two projecting rings are raised in the groove between which the wire is wrapped. This glass knob is attached to an iron shank as represented in fig. 18, which is driven into the post.

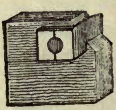
Fig. 17.

Fig. 18.



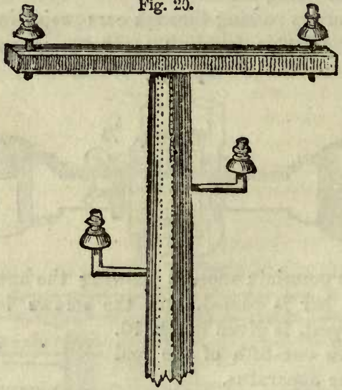
Another form of support used on these lines is represented in fig. 19, which consists of two rectangular blocks of glass, in each of which is a semi-cylindrical groove corresponding with the thickness of the conducting wire, so that the wire being laid in the groove of one of them, and the other being laid upon it, will be completely enclosed within the block of glass produced by their union. These blocks of glass are surrounded and protected by a larger block of wood, as represented in the figure, where the white part represents the glass, and the shaded part the wood.

Fig. 19.



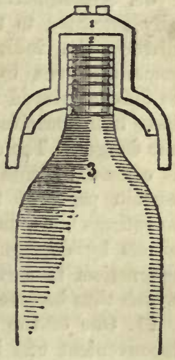
The supports are sometimes attached to the sides of the posts, and sometimes placed upon an horizontal cross bar, as represented in fig. 20.

Fig. 20.



The supports used in House's lines consist of a glass cap about five inches in length and four inches in diameter, having a coarse screw-like surface cut inside and out. This glass cap (2) fig. 21 is screwed and cemented into a bell-shaped iron cap (1) from three to four pounds, in weight, projecting an inch below the lower edge of the glass, protecting it from being broken; this is fitted with much care to the top of the pole (3), and is covered with paint or varnish. The conducting wire is fastened to the top of the cap by projecting iron points, and the whole of the iron cap is thus in the circuit, as the wire is of iron and not insulated. To prevent the deposit of moisture, the glass is covered by a varnish of gum-lac dissolved in alcohol, and the ring-like form of the glass is to cause any moisture to be carried to the edge and there drop off.*

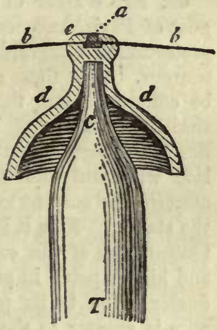
Fig. 21.



The wires on the American lines are not usually galvanised.

57. One of the forms of insulating support used on the German lines is represented in fig. 22, and consists of an insulating cap placed on the tapering end of a post T. The post terminates in a point *c*, an inch and a half in length and about six lines in diameter; this pole is covered with a porcelain cap *d d*, a sort of reversed cup; on its summit *e*, there is a hole inlaid with lead, in which the conducting wire *b b* enters; this insulator is then covered with a roof.

Fig. 22.




58. It may be asked what prevents the escape of the electric fluid from the surface of the wire between post and post? In general when wires are used on a smaller scale for the transmission of electric currents, the escape of the fluid is prevented by wrapping them with silk or cotton thread, which thus forms a non-conducting cover upon them, but on the scale on which they are used on telegraphic lines the expense of this, independently of the difficulty of protecting such covering from destruction by weather, would render it inadmissible.

59. The atmosphere, when dry, is a good non-conductor; but this quality is impaired when it is moist. In ordinary weather, however, the air being a sufficiently good non-conductor, a metallic wire will, without any other insulating envelope except the air itself, conduct the stream of electricity to the necessary distances. It is true that a coated wire, such as we have

* Turnbull on the Electric Telegraph, p. 176. Philadelphia, 1853.

described, would be subject to less waste of the electric fluid *en route;* but it is more economical to provide batteries sufficiently powerful to bear this waste, than to cover such extensive lengths of wire with any envelope.

60. Atmospheric electricity having been found to be occasionally attracted to the wires, and to pass along them, so as to disturb the indications of the telegraphic instruments, and sometimes even to be attended with no inconsiderable danger to those employed in working the apparatus; various expedients have been contrived for removing the inconvenience and averting the danger. The current produced by this atmospheric electricity is often so intense as to render some of the finer wires used in certain parts of the apparatus at the stations, red hot, and sometimes even to fuse them. It also produces very injurious effects by demagnetising the needles, or imparting permanent magnetism to certain bars of iron included in the apparatus, which thus become unfit for use.

61. One of the expedients used for the prevention of these inconvenient and injurious effects is to place common lightning conductors on the posts. The points of these are shown upon the posts in figs. 10, 11, and 12.

62. Mr. Walker of the South Eastern Company and M. Breguet of Paris, have each invented an instrument for the better protection of telegraphic stations from atmospheric electric discharges. Both these contrivances have been found in practice to be efficacious, and though differing altogether in form they are similar in principle. In both, a much finer wire than any which lies in the regular route of the current is interposed between the line wire and the station, so that an intense and dangerous atmospheric current must first pass this fine wire before reaching the station. Now it is the property of such a current to raise the temperature of the conductor over which it passes to a higher and higher point in proportion to the resistance which such conductor offers to its passage. But the resistance offered by the wire is greater in the same proportion as its section is smaller. The safety wire interposed in these contrivances is, therefore, of such thinness that it must be fused by a current of dangerous intensity. The wire being thus destroyed all electric communication with the station is cut off, and the extent of the inconvenience is the temporary suspension of the business of the line until the breach has been repaired.

Expedients are used on the American lines to divert the atmospheric electricity from the wires, consisting merely of a number of fine points projecting from a piece of metal connected with the earth by a rod of metal. These points are presented to a metal plate, or other surface, attached to the line wire at the place where it enters the station. It is found that these points attract the atmospheric electricity, which passes to the ground by the conductor connected with them, but do not attract the electricity of the battery current.

63. The wires extended from post to post are continued in passing the successive stations of the line. The expedients by which the current is turned aside from the main wire, and made to pass through the telegraphic office of the station, differ more or less in their details on different lines and in different countries, but are founded on the same general principles. It will therefore be sufficient here to describe one of those commonly used on the British lines.

The conducting wire of the main line in passing the station is cut and the ends jointed by a shackle, as represented in fig. 12, in the case of a winding post. This shackle breaking the metallic continuity would stop the course of the current. A wire is attached to the line wire below the shackle so as to receive the current which the latter would stop, and is carried on insulating supports into the telegraphic office and put in connection with the telegraphic instrument. Another wire connected with the other side of the instrument receives the current on leaving it, and being carried back on insulating supports to the line wire, is attached to the latter above the shackle, and so brings back the current which continues its progress along the line wire.

64. Although the mode of carrying the conducting wires at a certain elevation on supports above the ground has been the most general mode of construction adopted on telegraphic lines, it has been found in certain localities subject to difficulties and inconvenience, and some projectors have considered that in all cases it would be more advisable to carry the conducting wires underground.

This underground system has been adopted in the streets of London, and of some other large towns. The English and Irish Magnetic Telegraph Company have adopted it on a great extent of their lines, which overspread the country. The European Submarine Telegraph Company has also adopted it on the line between London and Dover, which follows the course of the old Dover mail-coach road by Gravesend, Rochester and Canterbury.

65. The methods adopted for the preservation and insulation of these underground wires are various.

The wires proceeding from the central telegraph station in London are wrapped with cotton thread, and coated with a mixture of tar, resin, and grease. This coating forms a perfect insulator. Nine of these wires are then packed in a half-inch leaden pipe, and four or five such pipes are packed in an iron pipe about three inches in diameter. These iron pipes are then laid under the foot pavements, along the sides of the streets, and are thus conducted to the terminal stations of the various railways, where they are united to the lines of wire supported on posts along the sides of the railways, already described.

66. Provisions, called *testing posts*, are made at intervals of a quarter of a mile along the streets, by which any failure or accidental irregularity in the buried wires can be ascertained, and the place of such defect always known within a quarter of a mile.

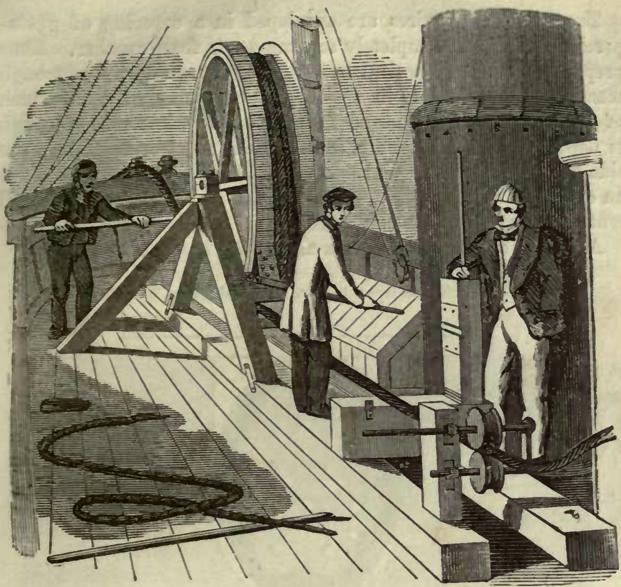


Fig. 34.—LAYING THE CABLE FROM THE DECK OF THE SHIP.

# THE ELECTRIC TELEGRAPH.

## CHAPTER III.

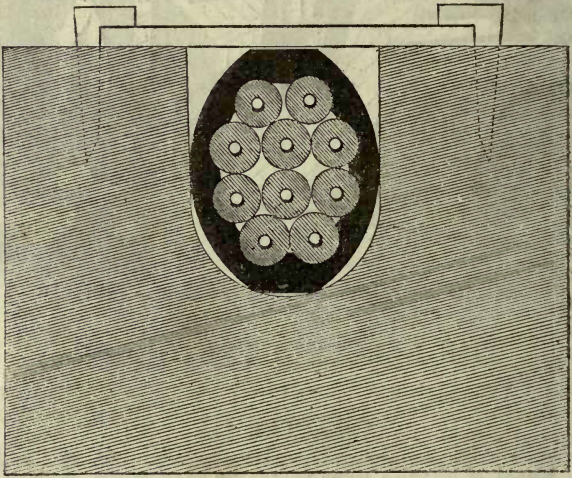
67. Wires of Magneto-electric Telegraph Company. — 68. Mr. Bright's method of detecting faulty points.—69. Such failure of insulation rare.—70. Underground method recently abandoned in Prussia.—71. Underground wires of the European and Submarine Company.—72. Imperfect insulation in tunnels.—73. Mr. Walker's method of remedying this.—74. Overground system adopted through the streets of cities in France, and in the United States.—75. Telegraphic lines need not follow railways.—76. Do not in America nor in certain parts of Europe.—77. Submarine cables.—78. Cable connecting Dover and Calais.—79. Failure of first attempt—Improved structure.—80. Table of submarine cables and their dimensions.—81. Dimensions and structure of the Dover and Calais cable.—82. Holyhead and Howth cable.—83. First attempt to lay cable between Portpatrick and Donaghadee—its failure.—84. Dover and Ostend.—85. Portpatrick and Donaghadee.—86. Orfordness and the Hague.

67. The wires of the Magnetic Telegraph Company are laid and protected in the following manner.

Ten conducting wires are enveloped in a covering of gutta-percha, so as to be completely separated one from another. Thus prepared they are deposited in a square creosoted wooden trough measuring three inches in the side, so that nearly a square inch of its cross section is allowed for each of the wires. This trough is deposited on the bottom of a trench cut two feet deep along the side of the common coach road. A galvanised iron lid, of about an eighth of an inch thick, is then fastened on by clamps or small tenter hooks, and the trench filled in.

A section of the trough in its actual size is given in fig. 23.

Fig. 23.—Galvanised Iron Lid, No. 14, Birmingham Wire Gauge.



Creosoted Deal Troughing.

The method of laying the wires in the streets adopted by this company is a little different. In this case iron pipes are laid, but they are split longitudinally. The under halves are laid down in the trench, and the gutta-percha covered wires being deposited, the upper halves of the pipes are laid on and secured in their places, by means of screws through flanges left outside for the purpose.

To deposit the rope of gutta-percha-covered wires in the trough it is first coiled upon a large drum, which being rolled along slowly and uniformly over the trench, the rope of wires is payed off easily and evenly into its bed.

So well has this method of laying the wires succeeded that in Liverpool the entire distance along the streets from Tithe Barn

Railway station to the Telegraph Company's offices in Exchange Street, East, was laid in eleven hours; and in Manchester the line of streets from the Salford Railway station to Ducie Street, Exchange, was laid in twenty-two hours. This was the entire time occupied in opening the trenches, laying down the telegraph wires, refilling the trenches and relaying the pavement.

68. One of the objections against the underground system of conducting wires, was, that while they offered no certain guarantee against the accidental occurrence of faulty points where their insulation might be rendered imperfect, and where, therefore, the current would escape to the earth, they rendered the detection of such faulty points extremely difficult. To ascertain their position required a tedious process of trial to be made from one testing post to another, over an indefinite extent of the line.

A remedy for this serious inconvenience, and a ready and certain method of ascertaining the exact place of such points of fault without leaving the chief, or other station at which the agent may happen to be, has been invented and patented by the Messrs. Bright of the Magnetic Telegraph Company.

Instruments called Galvanometers, which will be more fully described hereafter, are constructed, by which the relative intensity of electric currents is measured by their effect in deflecting a magnetic needle from its position of rest. The currents which most deflect the needle have the greatest intensity, and currents which equally deflect it have equal intensities.

The intensity of a current diminishes as the length of the conducting wire—measured from the pole of the battery to the point where it enters the earth—is augmented. Thus, if this length be increased from twenty miles to forty miles, the intensity of the current will be decreased one half.

The intensity of the current is also decreased by decreasing the thickness of the conducting wire. Thus the intensity, when transmitted on a very thin wire, will be much less than when transmitted on a thick wire of equal length; but the thick wire may be so much longer than the thin that its length will compensate for its thickness, and the intensity of the current transmitted upon it may be equal to that transmitted on the shorter and thinner wire.

The method of Messrs. Bright is founded upon this property of currents. A fine wire wrapped with silk or cotton so as to insulate it and prevent the lateral escape of the current, is rolled upon a bobbin like a spool of cotton used for needle-work. A considerable length of fine wire is thus comprised in a very small bulk.

The wire on such a bobbin being connected by one end with the wire conducting a current, and by the other end with the earth, will transmit the current with a certain intensity depending on its length, its thickness, and, in fine, on the conducting power of the metal of which it is made.

Now let us suppose that a certain length of the wire of the telegraphic line be taken, which will transmit a current of the same intensity. A galvanometer placed in each current will then be equally deflected. But if the length of the line wire be less or greater than the exact equivalent length, the galvanometer will be more or less deflected by it than it is by the bobbin wire, according as its length is less or greater.

It is, therefore, always possible by trial to ascertain the length of line wire, which will give the current the same intensity as that which it has upon any proposed bobbin wire.

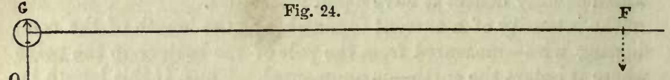
Bobbins may therefore be evidently made carrying greater or less lengths of wire upon which the current will have the same intensity as it has upon various lengths of line wire.

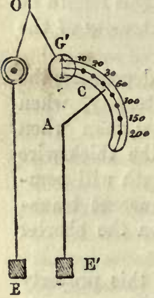
Suppose then a series of bobbins provided, which in this sense represent various lengths of line wire from 100 feet to 300 miles, and let means be provided of placing them in metallic connection in convenient cases.

Such an apparatus is that by which the Messrs. Bright detect the points of fault.

Let B be the station battery, G a galvanometer upon the line wire, F the point of fault at which the current escapes to the

Fig. 24.




earth, in consequence of an accidental defect of the insulation. Let a wire be attached to the line wire of the station, at O, and let it be connected with the first of a series of bobbins such as are described above; let a galvanometer, similar to G, be placed upon it at G′. Let a metallic arm A C, turning on the point A, be so placed that its extremity C shall move over the series of bobbins, and that by moving it upon the centre A, the end C may be placed in connection with the wire of any bobbin of the series. Let A be connected by a conducting wire with the earth at E′, the negative pole of the battery B being connected with the earth at E.

The apparatus being thus arranged, let us suppose that the wire A C is placed in connection with the first bobbin, representing 10 miles of the line wire, and that the distance G F of the point of fault is 145 miles. In that case the battery current will be divided at O, between the two wires O G and O G′, but the chief part will flow by the shortest and easiest route, and the galvanometer G′ will be very much, and G very little, deflected. This will show that F must be very much more than 10 miles from the station. The arm A C will then be turned successively from bobbin to bobbin. When directed to the second bobbin, the current on O G′ will have the same intensity as if it flowed on 20 miles of line wire, when turned to the third the same as if it flowed on 30 miles of line wire, and so on. The needle of G′ will, therefore, continue to be more deflected than that of G, although the difference will be less and less, as the number of bobbins brought into the circuit is increased. When the bobbins included represent 140 miles, G′ will be a little more, and when they represent 150 miles it will be a little less deflected than G, from which it will be inferred that the point of fault lies between the 140th and the 150th mile from the station. A closer approximation may then be made by the introduction of shorter bobbins, and this process may be continued until the place of the fault has been discovered with all the accuracy necessary for practical purposes.

69. It appears nevertheless, that in the practical working of the telegraphic lines, occasions for the application of these expedients are of extremely rare occurrence. During the four winter months of November, December, January, and February 1853-54, distances of 300 miles of underground wire, without any break of circuit, have been in constant operation under the Magnetic Telegraphic Company, and notwithstanding an unusual prevalence of unfavourable weather, with frequent and continued snow-storms, no stoppage whatever has taken place.

70. The Prussian underground lines of wire have been attended, however, with occasional failures, which have produced some public inconvenience. This circumstance has been ascribed to the faulty method of laying the wires. The gutta-percha enveloping them was mixed with sulphur, a process called *Vulcanisation*. Upon being deposited in the ground the sulphur was soon abstracted, leaving the gutta-percha brittle and porous.

71. The under-ground line of the European and Submarine Company, from London to Dover, is laid down in nearly the same manner as that of the Magnetic Company. There are six conducting copper wires encased in gutta percha. To detect the more easily the place of any accidental breach of continuity, a box is placed at the end of each mile, in which a few yards of the continuous line of wire are coiled, so that in case of any accidental interruption occurring to the flow of the current, the particular mile in which that interruption exists can always be ascertained by putting the coils at the end of each successive mile in

connection with a portable battery. The current will fail at the particular mile within which the fault has taken place.

72. In passing through tunnels the overground wires have been subject to great inconvenience, owing to the quantity of water percolating through the roof, constantly falling on the wires and their supports, and thus injuring their insulation. It has been found that from this cause the current transmitted along one wire has been subject to leakages, a part of it passing by the moisture which surrounds the supports to an adjacent wire, so that being thus divided, part either returns to the station from which it has been transmitted, or goes on to a station for which it is not intended.

73. This inconvenience would be removed by adopting for tunnels the under-ground system. Mr. Walker, to whom great experience in the practical business of electric telegraphy, and considerable scientific knowledge must give much authority on such a subject, has adopted apparently with very favourable results a method of covering the wires, which pass through tunnels, with a coating of gutta-percha. The conducting wire thus treated is copper wire No. 16. The gum being well cleaned and macerated by steam, is put upon the wire by means of grooved rollers. The diameter of the covered wire is a quarter of an inch. Mr. Walker states that in all the wet tunnels under his superintendence he has substituted this gutta-percha-covered wire for the common line wire, and has thus "accomplished telegraphic feats which could not have been attempted on the old plan."

74. In France and in the United States the wires, even in the cities and towns, are conducted on rollers at an elevation, as on other parts of the lines. In Paris, for example, the telegraphic wires proceeding from the several railway stations are carried round the external boulevards and along the quays, the rollers being attached either to posts or to the walls of houses or buildings, and are thus carried to the central station at the Ministry of the Interior.

75. In Europe, the telegraphic wires have until very lately invariably followed the course of railways; and this circumstance has led some to conclude that, but for the railways, the electric telegraph would be an unprofitable project.

76. This is however a mistake. Independently of the case of the Magnetic Telegraph Company already mentioned, the wires in the United States, where a much greater extent of electric telegraph has been erected and brought into operation than in Europe, do not follow the course of the railways. They are conducted, generally, along the sides of the common coach-roads, and sometimes even through tracts of country where no roads have been made.

It has been contended in Europe that the wires would not be safe unless placed within the railway fences. The reply to this is, that they are found to be safe in the United States, where there is a much less efficient police, even in the neighbourhood of towns, and in most places no police at all. It may be observed, that the same apprehensions of the destructive propensities of the people have been advanced upon first proposing most of the great improvements which have signalised the present age. Thus, when railways were projected, it was objected that mischievous individuals would be continually tearing up the rails, and throwing obstructions on the road, which would render travelling so dangerous that the system would become impracticable.

When gas-lighting was proposed, it was objected that evil-disposed persons would be constantly cutting or breaking the pipes, and thus throwing whole towns into darkness.

Experience, nevertheless, has proved these apprehensions groundless; and certainly the result of the operations on the electric telegraph in the United States goes to establish the total inutility of confining the course of the wires to railways. Those who have been practically conversant with the system both in Europe and in America, go further, and even maintain that the telegraph is subject to less inconvenience, that accidental defects are more easily made good, and that an efficient superintendence is more easily insured on common roads, according to the American system, than on railways.

These reasons, combined with the urgent necessity of extending the Electric Telegraph to places where railways have neither been constructed nor contemplated, have led to the general departure of the telegraphic wires from the lines of railway in various parts of the continent. In France, particularly, almost all the recently-constructed telegraphic network is spread over districts not intersected by railways, and even where railways prevail, the wires are often, by preference, carried along the common road.

77. When channels, straits, arms of the sea, or rivers of great width intervene between the successive points of a telegraphic line, the conducting wires are deposited upon the bottom of the water, protected from the effects of mechanical and chemical action by various ingenious expedients. A considerable number of such subaqueous conductors have been fabricated for telegraphic lines in various countries, and others are in progress or contemplated. Before June 1854, wire ropes had been made for the lines between Dover and Calais, Dover and Ostend, Dublin and Holyhead, Donaghadee and Portpatrick, England and Holland, the Zuyder Zee, the Great Belt (Denmark), the Mississippi, New Brunswick and Prince Edward's Island, and Piedmont and Corsica.

78. The earliest attempt to transmit a voltaic current under water for telegraphic purposes, is attributed to Dr. O'Shaughnessy, who is so well known for his successful exertions to establish the electric telegraph in India. He succeeded in 1839 in depositing an insulated conducting wire, attached to a chain cable, in the river Hoogly, by which the electric current was transmitted from one bank of that river to the other.

The first important project of this kind which was executed in Europe, was the connection of the coasts of England and France by the submarine cable, deposited in the bed of the channel between Dover and Calais. A concession being obtained from the French government on certain conditions, a single conducting wire, invested with a thick coating of gutta-percha, was sunk by means of leaden weights across the channel, and the extremities being put into connection with telegraphic instruments, messages were transmitted from coast to coast. One of the conditions of the French concession being that this should be effected before September, 1850, this object was attained, but nothing more; for the action of the waves near the shore constantly rubbing the rope against the rocky bottom, soon wore off the insulating envelope and rendered the cable useless.

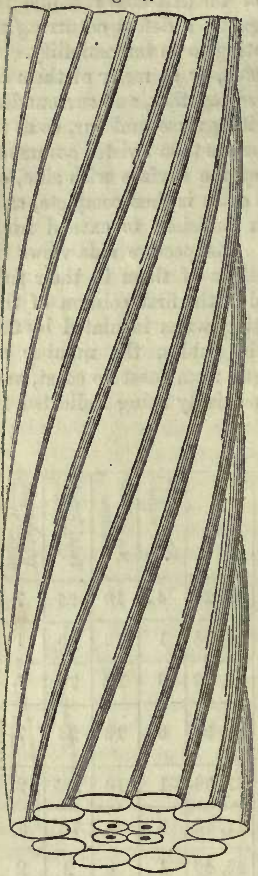
79. It is right to state that the projectors themselves did not expect from this first trial permanent success, and regarded it merely as the experimental test of the practicability of the enterprise. It was, therefore, immediately resolved to resort to means for the effectual protection of the conducting wires from the effects of all the vicissitudes to which they would be exposed. With this view, Messrs. Newall and Co., the eminent wire-rope makers of Gateshead, were charged with the difficult and unprecedented task of discovering expedients, by which a cable of gutta-percha containing the conducting wires could be invested with an armour of iron, at the same time so strong as to resist the action of the forces to which it would be exposed, and yet not too ponderous or too rigid to allow of being deposited in the bed of the channel. The result was the invention of the form of submarine cable, which has since been successfully adopted upon the various lines of international electric communication which will be presently described.

The conducting wires inclosed in these cables are usually copper wires, having a diameter of the sixteenth of an inch. Each wire is first separately covered with two coatings of gutta-percha. Each successive coating increases the thickness by a certain fraction of an inch. The object of laying on this succession of coats of the gum, is to guard against accidental defects which might render the insulation imperfect. If such a defect happened to exist at any point of the first coat it would be covered by the second, the chances against a defect occurring at the same point of both coatings amounting to an impossibility.

80. The conducting wire thus invested, or so many of them as it is intended to deposit, are then twisted together, and surrounded with a mass of spun yarn, soaked with grease and tar, so as to form a compact rope. Around this rope are then twisted a number of stout iron wires, sometimes coated on the surface with zinc, or as it has been called, galvanised. The cable is then complete, and is fabricated in one continued length sufficient to extend from shore to shore, or from bank to bank. Perspective side views of the several cables, and transverse sections of them in their full size, are given in the figures indicated in the first column of the following table, the number of conducting wires insulated by the gutta-percha and included within the cables, the number of surrounding iron wires, the total length from coast to coast, and the weight of the cables per mile respectively being indicated in the other columns.

| | Fig. | No. of copper wires. | No. of iron wires. | Total length —Miles. | Weight per mile—Tons |
|---|---|---|---|---|---|
| Dover and Calais . . . . . | 25, 26 | 4 | 10 | 25 | 7 |
| Holyhead and Howth . . . . | 27, 28 | 1 | 12 | 70 | 1 |
| Dover and Ostend . . . . . | 31, 32 | 6 | 12 | 70 | 7 |
| Portpatrick and Donaghadee (Magnetic Comp.) . . . . . | 35, 36 | 6 | 12 | 25 | 7 |
| Orfordness and the Hague . . . | 37, 38 | 1 | 10 | 135 | 2 |
| Across the Great Belt (Denmark) . . | 41, 42 | 3 | 9 | 16 | 5 |
| Across the Mississippi . . . . | 45, 46 | 1 | 8 | 2 | 2 |
| Across the Zuyder Zee . . . | 43, 44 | 6 | 10 | 5 | $7\frac{1}{2}$ |
| Newfoundland & Prince Edward's Island | 39, 40 | 1 | 9 | 150 | $1\frac{3}{4}$ |
| Portpatrick and Donaghadee (British Comp.) . . . . . . | 35, 36 | 6 | 12 | 27 | 7 |
| Spezzia and Corsica . . . . | 35, 36 | 6 | 12 | 110 | 8 |
| Corsica and Sardinia . . . . | 35, 36 | 6 | 12 | | 8 |

Fig. 25.



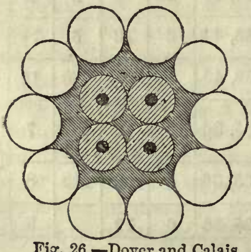


Fig. 26.—Dover and Calais.

81. In the Dover and Calais cable, which was the first fabricated and laid, each of the four copper wires are surrounded by gutta-percha, which in fig. 26 is indicated by the light shading round the black central spot, representing the section of the copper wire. The four wires thus prepared were then enveloped in the general mass of prepared spun yarn, represented by the darker shading. The ten galvanised iron wires were then twisted around the whole, so as to form a complete and close armour. The external form and appearance of this heliacal coating is represented in fig. 25.

This cable which was completed by Messrs. Newall and Co., in three weeks, measured originally 24 miles in length. Owing to the manner in which it was laid down this was found insufficient to extend from coast to coast, although the direct distance is only 21 miles. It was therefore found necessary to manufacture an additional mile of cable, which being spliced on to the part laid, the whole was completed, and the electric communication between Dover and Calais definitively established on the 17th October, 1851.

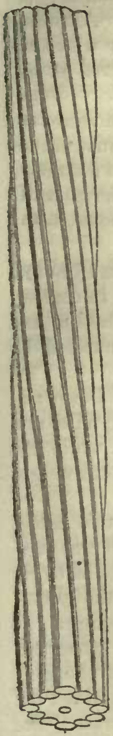
The cost of the cable itself was 9000*l.*, being at the rate of 360*l.* per mile. The total cost for cable and stations at Dover and Calais was 15,000*l.*

82. The next submarine cable laid down was that which connected Holyhead on the Welsh with Howth on the Irish coast. While several companies which had been formed for the purpose, were occupied in raising the capital necessary for this project, they were surprised by the

announcement that the project was already on the point of being realised by Messrs. Newall and Co., on their own account.

The distance between the points to be connected being 60 miles, the cable was made with a length of 10 addition miles, to meet contingencies. In this cable, which enclosed only one conducting wire, the external wires enclosing the insulating rope were made thicker at the parts near the shores than for that which lies in deep water, the former being subject to much greater disturbing forces. A side view of the part immersed in deep water is given in fig. 27, and a cross-section in fig. 28. A side view of the shore ends is given in fig. 29, and a cross-section in fig. 30, all being in their full size.

Fig. 27.



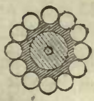


Fig. 28.
Holyhead and Howth.
Deep sea part.

Fig. 29.

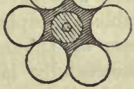


Fig. 30.
Holyhead and Howth.
Shore ends.

The gutta-percha rope was fabricated by the Gutta Percha Company in the City-road, London, from whence it was sent to Gateshead, where it received the iron wire envelope at the works of Messrs. Newall and Co., in the short space of four weeks. Loaded on twenty waggons, it was next sent by railway across England to Maryport, where it was embarked on board the "Britannia," and transported to Holyhead. On the morning of the 1st June, 1852, one of its extremities being established at Holyhead, it was laid in the bed of the channel. This was done as follows:—The cable was very carefully coiled in the hold of the steamer; one end was then passed several times round a brake-wheel, and was conveyed on shore, when it was attached to a telegraph instrument. The other or lower end of the cable was attached to another instrument in the cabin of the steamer, so that any message passing from instrument to instrument, was conveyed through the entire cable in the hold, and round the brake-wheel as the cable passed off in the process of submersion. The shore end having been made fast securely, the steamer was put in motion, and a certain strain was put on the cable by means of the brake-wheel, so that it was laid straight on the ground, or bottom of the sea.

The cable is seen as it rises from the hold in the foreground, (fig. 34, p. 145,) guided between rollers to the drum, and it again appears in the back ground, as it passes over the stern. A counter and indicator was applied to the shaft of the drum by which the length of cable which at any moment had been delivered off into the sea was shown.

The wind and tides have the effect of drawing the vessel out of her course, so that the quantity of cable expended must always be greater than the distance between the two points in a straight line. In the case of the Holyhead and Howth cable, the quantity expended was 64 miles. The depth of water is 70 fathoms, being more than twice that of Dover.

The entire process of laying it down was completed in 18 hours. In another hour the cable was brought ashore, and put in connection with the telegraphic wires between Howth and Dublin, and immediately afterwards London and Dublin were connected by means of instantaneous communication.

This cable was lighter considerably than that between Dover and Calais, its weight being a little less than one ton per mile, and consequently its total weight did not exceed 80 tons, while the Dover and Calais cable weighing 7 tons per mile, its total weight was 180 tons.

From some cause, which could not be ascertained, this cable, after being worked for three days, became imperfect. It was supposed to have been caught by the anchor of some vessel, for on being taken up lately, it was found broken near Howth, and the gutta-percha and copper wire stretched in an extraordinary manner.

83. On the 9th October, 1851, Messrs. Newall and Co. attempted to lay a cable across the narrowest part of the Irish channel, between Port Patrick and Donaghadee. This cable contained six conducting wires, similar to fig. 43. The distance across is the same as between Dover and Calais, viz., 21 miles, and 25 miles of cable were placed on board the "Britannia" steamer. The process of submersion was carried on until 16 miles had been successfully laid down, when a sudden gale came on, which rendered it impossible to steer the vessel in the proper course, and Mr. Newall was reluctantly compelled to cut the cable, when within 7 miles of the Irish coast, and having 9 miles of cable remaining on board.

The whole of this 16 miles of cable has been recovered in

June, 1854, after being nearly two years submerged. This proved a most arduous undertaking. The depth of the water in this part of the Irish channel is 150 fathoms, or 900 feet, and from this depth the cable was dragged by means of a powerful apparatus worked by a steam engine placed on the deck of a steamer. The operation occupied four days, for from the great force of the tide, which runs at the rate of 6 miles an hour, it was found impossible to work except at the times of high and low water. The cable was also imbedded in sand, so that the strain required to drag it up was occasionally very great.

The recovery of this cable has so far solved the question of the durability of submarine telegraphs. It was found nearly as sound as when laid down. There was a slight corrosion in certain parts which appeared to have been imbedded in decaying sea weed—the parts imbedded in sand were quite sound, and on other parts, which appeared to have rested on a hard bottom, there were a few zoophytes. The cable on being tested was found as perfect in insulation as when laid down.

84. The next great enterprise of this kind, of which the accomplishment must render for ever memorable the age we have the good fortune to live in, was the deposition in the bed of the Channel of a like cable connecting the coasts of England and Belgium, measuring SEVENTY MILES IN ONE UNBROKEN LENGTH! This colossal rope of metal and gutta-percha was also constructed at the works of Messrs. Newall and Co.

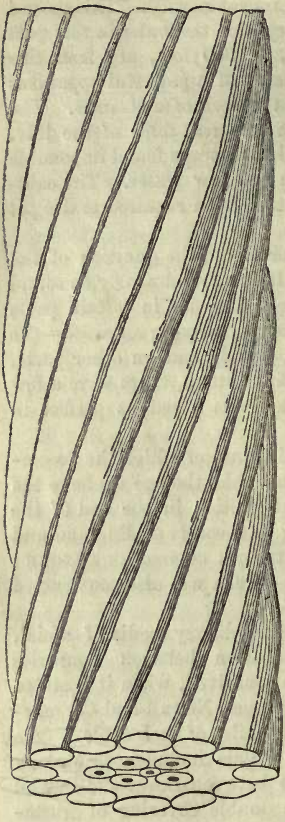
The probable extension of these extraordinary media of social, commercial, and political communication between countries separated by arms of the sea, may be conceived, when it is stated that during the winter of 1852-53 Messrs. Newall and Co. executed under contracts not less than 450 miles of such cable.

The cable laid between Dover and Calais includes, as already stated, four conducting wires. That between Dover and Ostend contains six wires insulated by the double covering of gutta-percha, manufactured, under Mr. S. Statham's directions, by the Gutta Percha Company. The gutta-percha laid into a rope is served with prepared spun-yarn, and covered with twelve thick iron wires, of a united strength equal to a strain of 40 to 50 tons —more than the proof strain of the chain cable of a first rate man-of-war.

A side view and section of this cable in its natural size are given in figs. 31 and 32 (page 158).

The Belgian cable weighed 7 tons per mile, so that its total weight was about 500 tons. Its cost was 33,000*l*. It took 100 days to make it, and 70 hours to coil it into the vessel from which it was let down into the sea, and 18 hours to submerge it.

Fi 31.



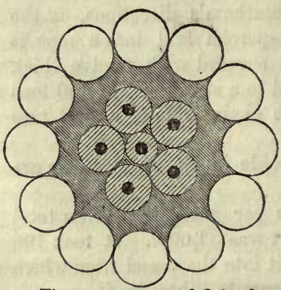


Fig. 32.—Dover and Ostend

The form in which it was coiled in the hold of the vessel is represented in fig. 33 (p. 129).*

On the morning of the Wednesday, the 4th May 1853, the vessel called the "William Hutt," Capt. Palmer, freighted with the cable, being anchored off Dover, near St. Margaret's, South Foreland, the process of laying the cable was commenced. This vessel was attended and aided by H.M.S. "Lizard," Capt. Rickets, R.N., and H.M.S. "Vivid," Capt. Smithett. Capt. Washington, R.N., was appointed, on the part of the Admiralty, to mark out the line and direct the expedition.

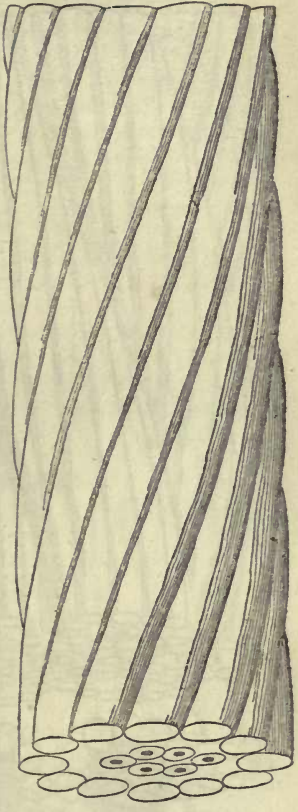
At dawn of day about 200 yards of the cable were given out from the "Hutt," and were extended by small boats to the shore, where the extremity was deposited in a cave at the foot of the cliff. There telegraphic instruments were provided by means of which, through the cable itself, a constant communication with the vessel was maintained during the arduous process, corresponding telegraphic instruments being placed on board the "Hutt."

At 6 o'clock, the process of laying commenced, the "Hutt" being taken in tow by the steam tug "Lord Warden."

The manner in which the cable was "payed out," as the vessel proceeded in its course, is represented in fig. 34 (p. 145), the cable as it came up from the hold, being

* This illustration, as well as that of the deposition of the cable, have been taken from the *Illustrated London News* of the 14th of May, 1853, by the consent of the publishers of that journal.

Fig. 35.



passed several times round a large brake-wheel, by means of which the cable was kept from going out too fast, and its motion maintained so as to be equal to the progress of the vessel. Men are represented in the figure applying the brake to the wheel.

On arriving off Middlekerke, on the Belgian coast, a boat sent from shore took from 500 to 700 yards of the cable on board, for the purpose of landing it. The boats of the British vessels taking her in tow, the end of the cable was safely landed, and deposited in a guard-house of the Custom House, where the telegraphic instruments brought in the "Hutt" being erected, and the communications made, the following despatch was transmitted direct to London :—

*Union of Belgium and England, twenty minutes before one*, p.m. *6th May* 1853.

85. The next submarine cable laid, was that of the Magnetic Telegraph Company, connecting Donaghadee with Port Patrick, also manufactured by Messrs. Newall and Co.

This cable, which contains six conducting wires, is represented in its proper size in figs. 35, 36, and corresponds in weight and form to the Belgian cable. But in the details of its construction and composition, some improvements were introduced. This rope was manufactured in 24 days, and cost about 13,000*l*.

The cable laid down by the British Telegraph Company between the same points, is precisely similar to this.

86. It is proposed to connect Orfordness, on the Suffolk coast, with the Hague, by seven separate submarine cables, each containing a

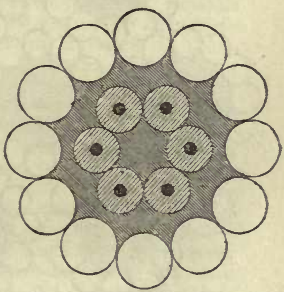
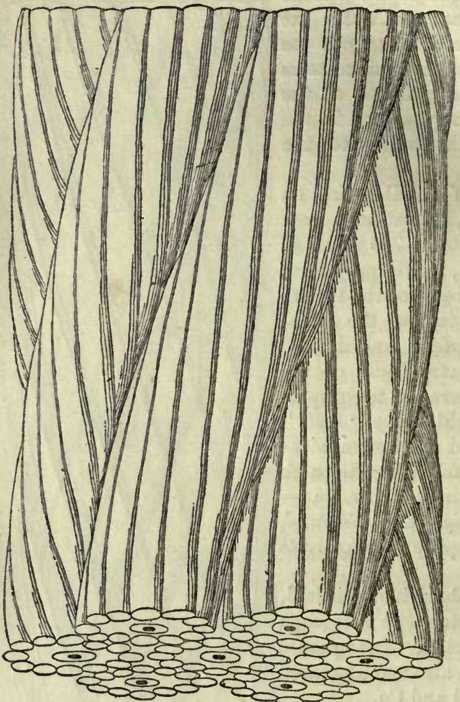


Fig. 36.—Donaghadee and Portpatrick. (Magnetic Telegraph Company.)

Fig. 37.



single wire. Near the shore on each side these will be brought together and twisted into a single great cable, as represented in figs. 37, 38.

Of these, only three have been laid down. The distance from Orfordness to the Hague being 120 miles, the cables were made 135 miles in length. They were laid down separately at a little distance one from another. At $3\frac{1}{2}$ miles from the shore they were brought together. When the telegraphic business increases the other four will be deposited.

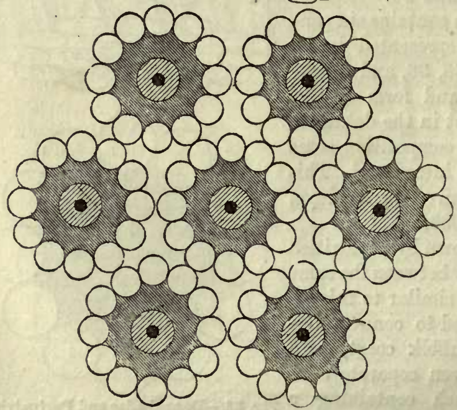


Fig. 38.—Orfordness and the Hague.

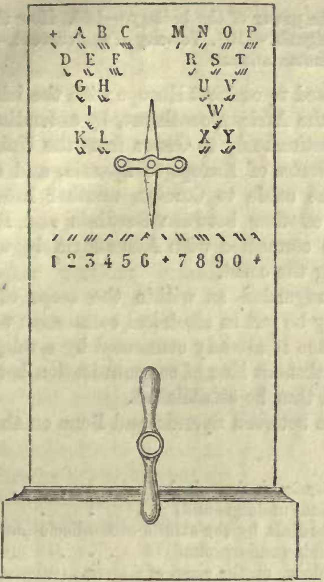



Fig. 66.—THE SINGLE NEEDLE TELEGRAPH.

# THE ELECTRIC TELEGRAPH.

## CHAPTER IV.

87.—Cable between Spezzia and Corsica.—88. Other cables, European and American.—89. Objections brought by scientific authorities to the submarine cables—Answers to these by practical men.—90. Example of a cable uninjured by the action of the sea.—91. Precautions necessary in laying the cable.—92. Accident in laying the Calais cable.—93. Imperfection attributed to the Belgian cable.—94. Transatlantic Ocean Telegraph.—95. Underground wires between the Strand and Lothbury.—96. Effect of the inductive action of underground or submarine wires.—97. Possible influence of this on telegraphic operations.—98. Examples of overground wires extended to great distances without intermediate support—between Turin and Genoa.—99. Telegraphic lines in India.—100. Difficulties arising from atmospheric electricity—height and distance of posts—mode of laying underground wires—extent of line erected to April 1854.—101. Intensity of current decreases as the length of wire increases.—102. Also increases with the thickness of the wire.—103. And with the number of elements in the battery.—104. Result of Pouillet's experiments on the intensity of current.—105. Intensity produced by increasing the power of the battery.—106. How the current produces telegraphic signals.—107. Velocity of the current.—108. Transmission of signals instantaneous.

87. It is proposed to connect Europe with the islands of the Mediterranean and the African continent, by extending the wires which already run continuously to Genoa from the United Kingdom and the Northern States of Europe to Spezzia, and from that point to lay a submarine cable to Corsica, another between Corsica and Sardinia, and another between Sardinia and Bona. The latter place would be connected with Alexandria by underground wires extending along the coast.

It is even regarded as within the scope of probability that Alexandria may be put in electrical connection with Bombay; and as the latter place is already connected by a telegraphic line with Calcutta, a continuous line of communication between London and Calcutta would thus be established.

The distances between Spezzia and Bona on the coast of Algeria are:—

| | Miles. |
|---|---|
| Spezzia to Corsica (submarine) . . . . . . . | 76 |
| Across Corsica (underground) . . . . . . . | 128 |
| Corsica to Sardinia by the straits of Bonifacio (submarine) . | 7 |
| Across Sardinia (underground) . . . . . . | 203 |
| Sardinia to Bona, on the coast of Algeria, (submarine) about | 125 |
| | 539 |

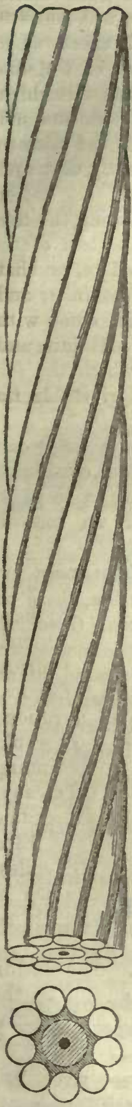
There would thus be 208 miles of submarine cable in three lengths of 76, 7, and 125 miles, and 331 miles of overland wires necessary to connect the southern coast of Europe with the northern coast of Africa.

This is the proposed plan, and the cables from Spezzia to Corsica, and from Corsica to Sardinia are already laid and in operation; but it will be obvious on inspecting the map that the object would be attainable with a less extent of submarine cable by continuing the overland line to Piombino, in the Grand Duchy of Tuscany, connecting that place with the Island of Elba by a submarine cable of 8 or 10 miles, and connecting the westernmost point of Elba with Bastia, in Corsica, by another cable of 35 to 40 miles. This method would have the further advantage of including in the line several important places on the Italian coast; such as, Carrara, Massa, Lucca, Pisa, and Leghorn.

A preference has been given to the course above described in consideration of the benefit conferred upon the company by the concession and guarantee granted by the government of Sardinia, which would not have been given had the other course been followed.

The cable now deposited contains six conducting wires, and is in all respects similar to that represented in figs. 35, 36.

Figs. 39, 40.



P. Edward's Island and N. Brunswick.

88. The short submarine cable laid down between Prince Edward's Island, and the coast of Nova Scotia (figs. 39, 40), is intended as part of a more extended submarine line connecting Newfoundland with Canada. The other sections would make up a total length of 140 miles; but the project is reported to be arrested for the present by the refusal of the House of Assembly of Nova Scotia to grant a charter to the company to cross that province.

The Danish submarine cable (figs. 41, 42), is carried across the Great Belt from Nyborg to Korsoe the nearest point of the opposite coast of Zealand.

The cable laid across the Zuyder Zee is shown in its proper size in figs. 43, 44 (p. 164).

Subaqueous cables have been laid across several of the American rivers. The difficulties supposed to attend the deposition and preservation of these conductors appeared to telegraphic engineers and projectors so formidable, that the wires were at first carried across the rivers between the summits of

Fig. 41.

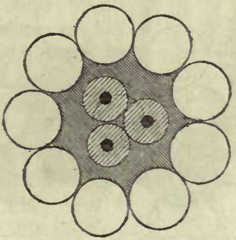
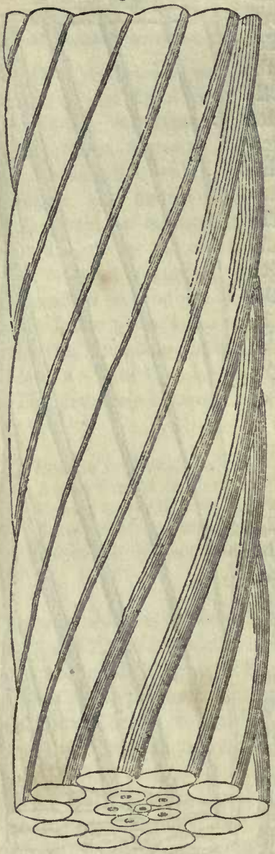


Fig. 42.—Great Belt.

Fig. 43.



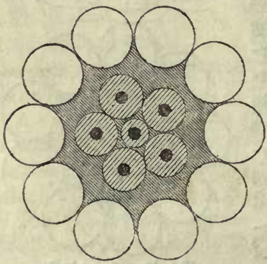


Fig. 44.—Zuyder Zee.

lofty masts erected on their banks. This method, however, was found to be attended with such effects as to render the maintenance of the wire impracticable. The masts were blown down by the violent storms and tornadoes incidental to the climate, and were not unfrequently destroyed by lightning.

The project of depositing the conducting wires in the bottom of the river was then resorted to, and has been carried into effect in several cases. The Ohio is crossed at Paducah by a cable containing one conducting wire, of which the following description is given in the American journals.

"It is composed of a large iron wire, covered with three coatings of *gutta percha*, making a cord of about five-eighths of an inch in diameter.

"To protect this from wear, and for security of insulation, there are three coverings of strong *Osnaburg*, saturated with an elastic composition of *non-electrics*; and around this are eighteen large iron wires, drawn as tight as the wire will bear, and the whole is then spirally lashed together with another large wire, passing around at every $\frac{3}{4}$ of an inch. The whole forms a cable of near two inches in diameter."

This cable is 4200 feet in length, being the longest yet laid down in the United States. It was constructed by Messrs. Shaffner and Sleeth.

Mr. Shaffner has also constructed and deposited subaqueous cables in the following places:—

Across the Tennessee river, four miles above Paducah, near its junction with the Ohio. Length, 2200 feet; same construction; deposited in 1851.

Across the Mississippi, at Cape Girondeau, in the State of Missouri. Length 3700 feet; deposited in 1853.

Across the Merimmac river, where it falls into the Mississippi, twenty miles below St. Louis. Length, 1600 feet; deposited in 1853.

All these are similar to the Paducah cable.

Across the Mississippi at St. Louis, three cables for different lines, each enclosed by 14 lateral external wires. Length, 3500 feet. Deposited in 1852-3.

Across the Ohio at Maysville, Kentucky, a cable containing two conducting wires, enclosed by 28 lateral external wires, constructed like the former. Length, 2700 feet. Deposited in 1853.

Across the Ohio at Henderson, Kentucky. Length, 3200 feet. Deposited in 1854.

Cables constructed by Messrs. Newall and Co. have also been deposited in the following places:—

Across the Mississippi at New Orleans, containing one conducting wire. Length, 3000 feet. Deposited in 1853. Shown in figs. 45, 46.

Across the Hudson, 10 miles above New York; similar construction. Length, 3600 feet. Deposited in 1854.

Across the Straits of Northumberland, at the mouth of the St. Lawrence; similar construction. Length, 10 miles. Deposited in 1853.

At certain places on the great western rivers serious difficulties have been and are still encountered in the preservation of these subaqueous conductors. At St. Louis on the Mississippi, and at Paducah on the Ohio, for example, several cables have been successively swept away by floods. Large trees carried down the stream are, one after another, stopped by being caught in the cable, and the number thus accumulated becomes at length so great that the force of the current, acting upon them, breaks it.

Another frequent cause of destruction to these cables in the Western Continent is the attraction they offer to atmospheric electricity. They are frequently destroyed by lightning. Mr. Shaffner

Fig. 45.

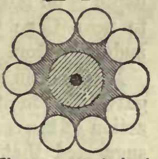


Fig. 46.—Mississippi.

tells me that he has sometimes found a longitudinal incision measuring ten feet in length, made in the gutta-percha, by the lightning, and cut as clean as if it had been done with a razor. At other times he has found the gutta-percha swelled, rough and porous, and sometimes pierced with countless numbers of openings like pinholes.

These appearances are supposed by Mr. Newall to arise from imperfection in the covering of the wire. The slit, he thinks, is caused, by air getting in behind the arm, which holds the mandril through which the copper wire passes before leaving the cylinder, and the porous covering arises from air mixed with the gutta-percha. Mr. Newall has ascertained that a wet hair, or a hole of equal size is sufficient to destroy the insulation of the wire.

89. Some eminent scientific authorities express doubts as to the durability of the submarine cables. In the case of the Dover and Calais cable it has been observed that the bottom of the channel at that part of the strait is proved by the soundings to be subject to undulations, so considerable that the summits of some of its elevated points rise to such a height that the water which covers them is not deep enough to secure them from the effects of the tumultuous agitation of the surface in violent storms. It is here well to remind the reader that the agitation of the ocean, which seems so awful in great tempests, has been found to extend to a very limited depth, below which the waters are in a state of the most profound repose. The objection we now advert to is, therefore, founded upon the supposition that the crests of some of the elevations upon which the submarine cable rests are so elevated as to be within that limit of depth, and it is feared that such being the case, the violence of the water in great tempests may so move the cable against the ground on which it is deposited with a motion to and fro, as to wear away by frequent friction its metallic armour, and thus expose the conducting wires within it to the contact of the water, and destroy their insulation.

But it has been most satisfactorily proved by a part of the experimental wire which was laid down between Dover and Calais, in 1850, and which was picked up two years afterwards in as perfect a state as when laid down, that the action of the waves does not affect the bottom of the Channel there. The greatest depth is 30 fathoms, and the bottom shelves regularly from Dover to near Cape Grinez, where there is a ledge of rocks rising suddenly from the bottom.

It has been also feared that, notwithstanding the effect of the galvanisation of the surface of the surrounding wires, the corrosive action of the sea water may in time destroy them; and it has been suggested that some better expedient for protection against this effect might be contrived upon the principle suggested by Davy, for the preservation of the copper sheathing of ships, by investing the cable at certain intervals with a thick coating or glove of zinc, which would increase the efficiency of the thinner coating of that metal given to it in the process of galvanisation.*

To this practical men who have had as much experience as is compatible with the recent date of these novel and extraordinary enterprises, reply that the results of their observations give no ground for apprehension of any injurious effects from tidal or tempestuous action, and that the fine iron used in the wire is not affected by sea water, as larger masses of coarser iron, such as anchors, are. They cite as proof of this, the slightly decayed state in which nails and small fire-arms have been found when recovered from vessels long sunk. They further state that the tar contained in the layer of hemp within the protecting wires acts as a preservative, whether the wires be galvanised or not. It has been found for example that, in the case of the submarine conductor between Donaghadee and Portpatrick, a perfect concrete of tar and sand has been already formed, upon which masses of shell-fish attach themselves at all parts that are not buried in sand, and it is apparent that in a few years a calcareous deposit will be formed around it, which will cement it to the bottom, and altogether intercept the action of the sea water.

90. In the deposition of submarine cables great care should be taken to select suitable points on the shore for beaching them. Sandy places are always to be sought. If this precaution be taken, it is affirmed that they are not subject to tidal action. A cable was partly laid by the Magnetic Telegraph Company in 1852 near Portpatrick (83), but abandoned in consequence of the vessel employed to deposit it being exposed in the process to a violent storm. The wire was left exposed upon the beach down to and beyond low water mark, and was in June, 1854, still in a perfect state, the galvanised iron wires, even to their zinc coating, being absolutely in the same state as when they were deposited.

91. It is contended by practical men that the great and only risk of failure in the submarine cables is from defects produced in the process of their deposition, or from original faults in the principle of their construction.

The greatest care is necessary in conducting the process of delivering out the cable into the sea, or "paying it out," as it is technically called. All sudden bending of the cable is to be especially avoided. "Kinks" or "hitches" are apt to occur in

* Pouillet, "Traité de Physique," vol. i. p. 799. Ed. 1853.

the process, by which the gutta percha covered wires within the cable are strained.

92. In laying the Calais cable it was found too short to extend to the opposite coast, and it became necessary to splice a supplementary piece to it. The joint thus formed afterwards failed, and it was found necessary to splice it anew, and to insert a fresh piece. Since this was done the cable appears to have continued in excellent order.

93. It is said that the Belgian cable has been subject to some imperfection arising from the position of the wires within the case. The sixth wire being in the axis of the cable, surrounded by the other five (see fig. 32), it was found that when the outer casing of the protecting wires was laid around it, the pressure on the centre wire rendered it imperfect, while the five surrounding it suffered to some extent.

Similar defects are said to exist in other cables constructed upon the same principle.

A hempen case well tarred in the centre is considered to form the best safeguard for the gutta percha covered wires in the process of making the cable, since it will yield to any compression itself without affecting injuriously the wire.

94. This notice of subaqueous telegraphy ought not to be concluded without some mention of the project for the deposition of an electric cable across the Atlantic, so as to put the Old World in instantaneous communication with the New. Such a scheme is regarded now pretty nearly as that for the electric connection of the British islands with each other and with the European continent was regarded some years ago. The sanguine consider the project practicable, and its speedy realisation probable. The more phlegmatic notice it only with ridicule. Men of science generally admit the possibility of the enterprise while men of finance more than doubt the possibility of a remunerative result.

The width of the Atlantic between the nearest points of British America and the west coast of Ireland is about sixteen hundred miles. Twelve cables, each as long as those which have been laid down between Orfordness and the Hague, would be sufficient to extend from coast to coast. That cable could be spliced to cable was practically proved between Calais and Dover, such a splice having been successfully made in the cable near the French coast.

Lieutenant Maury, of the United States, so well known for his hydrographical researches, caused a series of regular soundings to be made with the view of determining the form and condition of the bed of the ocean between the coasts of British America and

Ireland. He found that between Newfoundland, or the mouth of the river St. Lawrence, and the west coast of Ireland, the bottom consists of a plateau, which, as he says, "seems to have been placed there especially for the purpose of holding the wires of a submarine telegraph, and of keeping them out of harm's way. It is neither too deep nor too shallow; yet it is so deep, that the wires but once landed, will remain for ever beyond the reach of vessels, anchors, icebergs, and drifts of any kind; and so shallow that the wires may be readily lodged upon the bottom.

"The depth of this plateau is quite regular, gradually increasing from the shores of Newfoundland to the depth of 1500 to 2000 fathoms, as you approach the other side."*

Lieutenant Maury concludes that this line of deep sea soundings is quite decisive of the question, as to the practicability of a submarine telegraph between the two continents in so far as the bottom of the ocean is concerned. A cable laid across would pass to the north of the great banks, and would be deposited upon the plateau above described, where the waters of the ocean are proved to be "as still as those of a millpond."

This inference Lieutenant Maury deduces from the fact, that all the specimens of the bottom brought up have been found to consist of miscroscopic shells without the admixture of a single particle of gravel or sand. Had there been currents at those depths, these shells would have been thrown about and abraded, and mixed more or less with the *debris* of the natural bed of the ocean, such as ooze, sand, gravel, and other matter. "Consequently a telegraphic cable once laid there, there it would remain as completely beyond the reach of accident as if it were buried in air-tight cases."

Imperfectly informed persons have expressed an opinion that the cable would not sink below a certain depth, at which the increasing density of the sea water would render it bulk for bulk as heavy as the cable. The well known physical properties of water prove such a supposition to be groundless. Although not incompressible in an absolute sense, water is susceptible of compression, even at the greatest depths of the ocean, in so small a degree, that the cable must always greatly exceed it in specific weight.

Putting out of view the financial part of the question, there appears then to be no good reason for pronouncing the project to construct such a cable, and to deposit it in the bed of the ocean, impracticable in an absolute sense.

* Report of Lieutenant Maury to the Secretary of the U. S. Navy, Feb. 22, 1854.

It may be asked whether, if deposited, an electric current could be transmitted through it so as to produce telegraphic signals?

There can be only two reasons for doubting this—*first*, the length of the conducting wire, and, *secondly*, the inductive effects of the water upon the cable.

The intensity of the current transmitted by a battery of given power upon a wire, is in the direct ratio of the conducting power of the wire and the magnitude of its transverse section, and in the inverse ratio of its length. A length so great as 1500 or 1600 miles, would of course considerably attenuate the current.

But it will be recollected that, in the experiments described in Chap. I. par. 9, made by M. Leverrier and myself, messages were transmitted over a space of 1000 miles of wire without intermediate battery power, and with a terminal battery of very limited power. In that case 336 miles of the wire upon which the current was transmitted were iron, a very indifferent conductor, and the remaining 746 miles were copper wire of extremely small diameter. It is certain, therefore, that by reason of the inferior conducting power of the one part, and of the very small transverse section of the other part, this length of 1082 miles offered a much greater resistance to the transmission of the current than would 1600 miles of copper wire, such as is usually selected for submarine cables.

But independent of these considerations, nothing would be easier than to give the copper wire enclosed in the cable such a thickness, and to apply to it such batteries, as would ensure the transmission of a current of sufficient intensity.

The effects of the recoil currents produced by the inductive action of the water upon the cable, cannot be so certainly appreciated with our present knowledge and experience; but although the effects of these are sensible in the cases of the submarine and underground wires already laid down, they have not produced any obstruction to the efficient performance of the telegraphs, and the managers of the Magnetic Telegraph Company, which works well several hundred miles of wire partly subaqueous and partly underground, assure me that no inconvenience or obstruction whatever is found to arise from this cause. If no other objection were raised against the project of a Transatlantic cable save this, it may be safely pronounced that there would be nothing to be apprehended which the resources of science and art would not easily surmount.

It does not appear, therefore, that any part of the great problem of subatlantic telegraphy remains to be solved, except that which is involved in the financial view of the question. If it be undertaken as a commercial enterprise with a view to a remunerative return, *will it pay?* Or, on the other hand, may it not be regarded as one of those vast international enterprises to which the influence and resources of states should be applied? These are questions which we have neither the space nor the vocation to discuss.

95. In 1852, the conducting wires which connect the Branch Telegraph Office, established in the Strand, opposite Hungerford Market, with the General Post-office, were laid down. In this case the conducting wires are galvanised brass instead of copper. They are as usual laid in iron tubes, and are carried along the kerb stones of the foot pavement of the Strand, Fleet-street, Ludgate-hill, and St. Paul's Church-yard to Cheapside, where they cross over to Foster-lane, and passing through the branch office in the hall of the General Post-office, are carried thence to the central telegraph station in Lothbury, at the rear of the Bank of England.

From this central office, at all hours by day and by night, despatches are transmitted to and received from every seaport and every considerable town in England, Scotland, and Wales; by the submarine wires, by Holyhead and Portpatrick, from all parts of Ireland, and by Dover, from all parts of the Continent of Europe where electric telegraphs have been constructed.

96. After the underground and submarine wires had been constructed and laid upon a considerable scale, the attention of Dr. Faraday was called by some of the parties engaged in their management to peculiar phenomena which had been manifested in the telegraphic operations made upon the lines thus laid. After experiments had been made upon a large scale with lines of subaqueous and subterranean wires, extending to distances varying from 100 to 1500 miles, it was found that the electricity supplied by the voltaic battery to the covered wire was in great quantity arrested there, by the attraction of electricity of an opposite kind evolved from the water or earth in which the wire is sunk; the attraction acting through the gutta percha covering exactly in the same manner as that in which the electricity developed by a common electric machine, and deposited on the inside metallic coating of an electric jar, acts through the glass upon the natural electricity of the external coating, or of the earth in connection with it. The two opposite electricities on the inside and outside of the coating of the wire by their mutual action neutralise each other, and under certain circumstances a person placing his hands in metallic connection with both sides of such coating, may ascertain the presence of a large charge of such neutralised fluid, by receiving the shock which it will give like that of a charged Leyden jar.

97. It is apprehended that this unforeseen phenomenon may

interfere more or less with the practical working of all telegraphs having underground conducting wires; and I have been informed by the agents engaged in bureaux of the Paris telegraph, that they are sensible of its effects in all direct communications between that capital and London.

On the other hand the Magneto-Electric Telegraph Company, who at the present time (May, 1854), have nearly 900 miles of underground wire in operation, report that they sometimes pass their signals without any difficulty through 500 miles of underground wire without any break or delay in the circuit, and that they have in constant operation continuous underground lines connecting towns above 300 miles apart.

The only defect complained of in the underground wires is that which proceeds from accidental failures of complete insulation, produced by defects in the gutta percha or other coating which allow moisture to penetrate in wet weather and to reach the conducting wire, or it may arise from accidental fracture of the wire. In any such cases the flow of the current to its destination is interrupted, and the telegraph conveys no signal.

The use of underground wires, and the discovery of the phenomenon of inductive action above described, are too recent to justify any certain inference as to their effects on telegraphic operations. Time and enlarged experience alone can settle the questions which have been thus raised.

98. Although as a general rule the overground lines of telegraphic wire are sustained by supports at intervals of about sixty yards, many exceptional cases are presented in which they are extended between supports at much greater distances asunder. Every recent visitor to Paris may have observed the long lines of wire which are in several cases extended along the boulevards and across the river.

But the most surprising examples of long lines of wires without intermediate support, are presented on the telegraphic line passing north and south through Piedmont between Turin and Genoa. There, according to a report published in the "Piedmontese Gazette," in the course of the line passing through the district intersected by the chain of the Bochetta, the engineer, M. Bonelli, had the boldness to carry the wires from summit to summit across extensive valleys and ravines at immense heights above the level of the ground. In many cases the distance between these summits amounted to more than half a mile, and in some to nearly three-quarters of a mile. In passing through towns, this line is carried underground, emerging from which it is again stretched through the air from crest to crest of the Maritime Apennines, after which it finally sinks into the earth, passing through Genoa under the streets and terminating in the Ducal palace.

It is stated that the insulation of the wires on this picturesque line has been so perfect, notwithstanding the adverse circumstances of its locality, that although it was constantly at work day and night during the first winter, no failure of transmission or extraordinary delay ever occurred.

99. Efforts have recently been made to extend the system of telegraphic intercommunication to India. Dr. O'Shaughnessy of the East India Company's medical department, in constructing an experimental line through a distance of 80 miles from Calcutta, used, instead of wires, iron rods, being the only obtainable materials. These were fastened together and supported on bamboos.

By experiments thus made, he found that the wires employed in Europe would be quite inadequate to the Indian telegraph. In England, where the lines are carried along railways, and where there are no living obstacles to contend with, the thin iron wire, called No. 8 gauge, answers its purpose well; but no sooner were the rods mounted on their bamboo supports in India than flocks of that largest of all birds, the adjutant, found the rods convenient perches, and groups of monkeys congregated upon them; showing clearly enough that the ordinary wire would be insufficient to bear the strains to which these telegraphic lines would be subjected. It was found also that not only must the wire be stronger, but that it must be more elevated, to allow loaded elephants, which march about regardless of roads or telegraphic lines, to pass underneath.

100. The telegraphic communication thus practically effected, is subjected to attacks to which the telegraphs in this country are but little exposed. Storms of lightning destroyed the galvanometer coils, and hurricanes laid prostrate the posts. Undaunted by the opposition of the elements, Dr. O'Shaughnessy contrived a lightning conductor for the instruments, and strengthened the supporting props.

Dr. O'Shaughnessy returned to England, and at Warley, near Brentwood, made arrangements for producing 3000 miles of thick galvanised wire, to be shipped for India; one of the earliest lines undertaken, to be from Calcutta to Bombay. One of the peculiar characteristics of the railway lines intended for India, as contrasted with the English lines, is the greater distance between the posts, which are higher and stronger than those generally used. The thick wire is raised to a height of fourteen feet, on posts nearly the eighth part of a mile apart. To obtain the necessary strength to bear the strain, the posts are fixed with screw piles. To show the strength of the wires thus extended, a rope was, for experiment, hung to the centre of the wire of largest span, and a soldier climbed up it, the weight of his body producing but a slight curvature. The common deflection arising from the weight of a wire of a furlong span does not exceed eighteen inches.

Dr. O'Shaughnessy's plan of underground communication, when such a mode of laying down the wires is desirable, is very economical. The copper wires coated with gutta percha, instead of being inserted in iron tubes, are inlaid in wooden sleepers, well saturated with arsenic, to protect them from the white ants, and they are then laid in a trench about two feet deep. An underground system of two wires may thus be laid down for 35*l*. the mile.

The plan adopted for joining the lengths of the thick galvanised wire is to have the two ends turned, so as to link into one another, which are then introduced into a mould, like a bullet-mould, and an ingot of zinc being cast over them, they form a most substantial joint, and perfect metallic connection.*

It appears from reports received in May, 1854, that at that date a telegraphic line was in full operation from Calcutta to Agra, a distance of 800 miles, and it was then expected that the entire line to Bombay, a distance of 1500 miles, would soon be completed and put in operation.

This line is reported to have been completed and brought into operation since the preceding paragraphs were in type.

---

101. To produce the effects, whatever these may be, by which the telegraphic messages are expressed, it is necessary that the electric current shall have a certain intensity. Now, the intensity of the current transmitted by a given voltaic battery along a given line of wire will decrease, other things being the same, in the same proportion as the length of the wire increases. Thus, if the wire be continued for ten miles, the current will have twice the intensity which it would have if the wire had been extended to a distance of twenty miles.

It is evident, therefore, that the wire may be continued to such a length that the current will no longer have sufficient intensity to produce at the station to which the despatch is transmitted those effects by which the language of the despatch is signified.

102. The intensity of the current transmitted by a given

* Year-Book of Facts, 1853, p. 150.

voltaic battery upon a wire of given length, will be increased in the same proportion as the area of the section of the wire is augmented. Thus if the diameter of the wire be doubled, the area of its section being increased in a fourfold proportion, the intensity of the current transmitted along the wire will be increased in the same ratio.

103. In fine, the intensity of the current may also be augmented by increasing the number of pairs of generating plates or cylinders composing the galvanic battery.

Since it has been found most convenient generally to use iron as the material for the conducting wires, it is of no practical importance to take into account the influence which the quality of the metal may produce upon the intensity of the current. It may be useful nevertheless to state that, other things being the same, the intensity of the current will be in the proportion of the conducting power of the metal of which the wire is formed, and that copper is the best conductor of the metals.

104. M. Pouillet found by well-conducted experiments, that the current supplied by a voltaic battery of ten pairs of plates, transmitted upon a copper wire, having a diameter of four-thousandths of an inch, and a length of six-tenths of a mile, was sufficiently intense for all the common telegraphic purposes. Now if we suppose that the wire instead of being four-thousandths of an inch in diameter, has a diameter of a quarter of an inch, its diameter being greater in the ratio of 62½ to 1, its section will be greater in the ratio of nearly 4000 to 1, and it will consequently carry a current of equal intensity over a length of wire 4000 times greater, that is, over 2400 miles of wire.

105. But in practice it is needless to push the powers of transmission to any such extreme limits. To reinforce and maintain the intensity of the current, it is only necessary to establish at convenient intervals along the line of wires intermediate batteries, by which fresh supplies of the electric fluid shall be produced, and this may in all cases be easily accomplished, the intermediate telegraphic stations being at distances, one from another, much less than the limit which would injuriously impair the intensity of the current.

106. Having thus explained the means by which an electric current can be conducted from any one place upon the earth's surface to any other, no matter what be the distance between them, and how all the necessary or desired intensity may be imparted to it, we shall now proceed to explain the expedients by which such a current may enable a person at one place to convey instantaneously to another place, no matter how distant, signs serving the purpose of written language.

It may be shortly stated that the production of such signs depends on the power of the agent transmitting the current to transmit, suspend, intermit, divert and reverse it at pleasure. These changes in the state of the current take place for all practical purposes simultaneously upon all parts of the conducting wire to whatever distance that wire may extend, for although strictly speaking there is an interval, depending on the time which the current takes to pass from one point to another, that interval cannot in any case exceed a small fraction of a second.

107. Although there is some discordance in the results of experiments made to determine the velocity of the current, they all agree in proving it to be prodigious. It varies according to the conducting power of the metal of which the wire is composed, but is not dependent on the thickness of the wire. On copper wire, its velocity, according to Professor Wheatstone's experiments, is 288000 miles; and according to those of MM. Fizeau and Gonelle, 112680 miles per second. On the iron wire used for telegraphic purposes, its velocity is 62000 miles per second, according to Fizeau and Gonelle; 28500 according to Professor Mitchell, of Cincinnati; and about 16000 according to Professor Walker of the United States.

108. It is evident therefore that the interval which must elapse between the production of any change in the state of the current at one telegraphic station, and the production of the same change at any other however distant, cannot exceed a very minute portion of a second, and since the transmission of signals depends exclusively on the production of such changes, it follows that such transmission must be practically instantaneous.

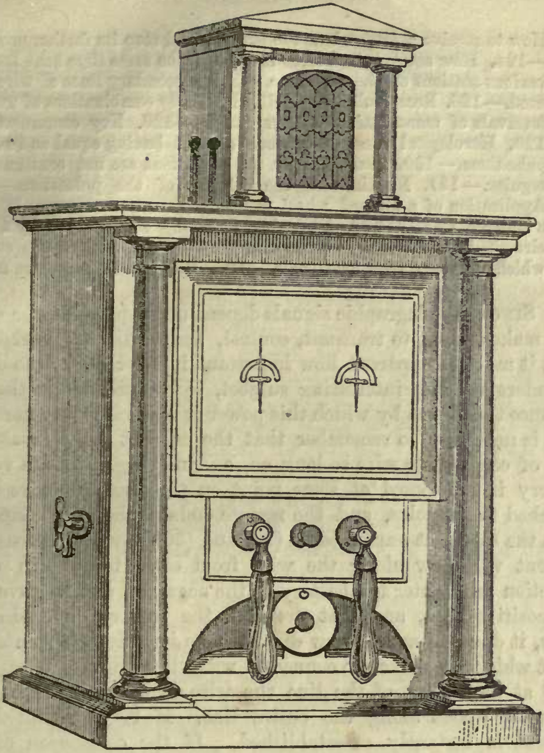


Fig. 68.—THE DOUBLE NEEDLE TELEGRAPH.

# THE ELECTRIC TELEGRAPH.

## CHAPTER V.

109. Current controlled by making and breaking the contact of conductors.—110. Instruments for controlling the current—commutators. —111. General principle of the commutator.—112. Its application to telegraphic operations.—113. To transmit a current on the up line only.—114. On the down line only.—115. On both lines.—116. To reverse the current.—117. To suspend and transmit it alternately.—118. How to manage a current which arrives at a station.—119. To make it ring the alarum.—120. Station with two alarums.—121. Notice of the station transmitting and receiving signals.—122. When signals not addressed to the station the current is passed on.—123.

How to receive a dispatch at the station, and stop its farther progress. —124. How several dispatches may be at the same time sent between various stations on the same line.—125. Secondary lines of wire then used.—126. Recapitulation.—127. Signals by combinations of unequal intervals of transmission and suspension.—128. Key commutator.—129. Horological commutator for a current having equal and regular pulsations.—130. Case in which the pulsations are not continuous or regular.—131. No limit to the celerity of the pulsations.—132. Application of a toothed wheel to produce the pulsations.—133. By a sinuous wheel.—134. Method of diverting the current by a short circuit, its application to the alarum.—135. Effects of the current which have been used for signals.—136. Deflection of magnetic needle.

109. Since all telegraphic signals depend on the power of the agent who makes them, to transmit, control, and modify the current at will, it must be apparent how important it is for those who desire to understand this interesting subject, to comprehend in the first instance the means by which this power is obtained and exercised.

It is necessary to remember that the current will flow along a line of conducting wire so long as, and no longer than, a voltaic battery is interposed at some point on the line, the wire being attached to its poles, and the remote ends of the wire connected with the earth, as explained in (23) and (36), and in that case the current will flow along the wire from earth to earth in such a direction as to enter the battery at the negative, and to leave it at the positive pole, and that provided the battery have adequate force, it does not matter how distant from its poles the points may be at which the wires are connected with the earth.

If at any point of the line the wire is broken, the current instantly ceases along the entire line. If it be reunited the current is instantly re-established. If the connection of the wire with the poles of the battery be reversed, so that the end which was connected with the positive is transferred to the negative pole, and *vice versâ*, the direction of the current along the entire line is reversed—since it must always flow *from* the positive and *to* the negative pole. If at any point the wire, being broken, be connected with another wire proceeding to the earth in any other direction, the current will be diverted to the latter wire, deserting its former course. If the wire conducting the current be connected at the same point with two wires both connected with the earth, it will be distributed between the two, the greater part, however, following that wire which offers the easier road to the earth.

These few principles, which are clear and simple, supply an easy key to the whole art of electro-telegraphy.

110. The class of mechanical expedients by which the agent who desires to transmit signals is enabled to control and modify the current in the manner here described, are called by the general

name of "COMMUTATORS," and are very various in form and arrangement according to the purposes to which, and the conditions under which they are applied. Not only do apparatus of this class differ in different countries where telegraphs have been established, but they vary upon different lines, and even on different parts of the same line. Without attempting to follow these endless variations, many of which are quite unimportant, and all of which are mere varieties in the application of the general principles explained above, we shall here confine ourselves to such an illustration of them as will at the same time render intelligible their structure and operation, and convey a general notion of the manner of transmitting and receiving signals.

111. Let us suppose that around the edge of a disc of ivory, wood, or any other insulating material, are inserted at convenient intervals pieces of metal, B, U, T, D, &c., fig. 47, which we shall call *contact pieces*, their purpose being to make and break the metallic contact which controls the current. At the back of the disc near these contact pieces are clamps or tightening screws by which conducting wires can be attached to them.

To an axis in the centre of the disc let two metallic hands, A A′ be attached, so that they can be turned round the disc like the hands of a clock, but having motions independent of each other. These hands may be supposed to be formed of elastic strips of metal bent at the ends towards the surface of the disc, so as to press upon it with some force: and let one of them move over the other without disturbing it, as the minute hand of a watch moves over the hour hand. Let A″ be another similar hand, turning on a centre fixed upon the contact piece E, so that it can be turned at pleasure upon one or other of the contact pieces P or N.

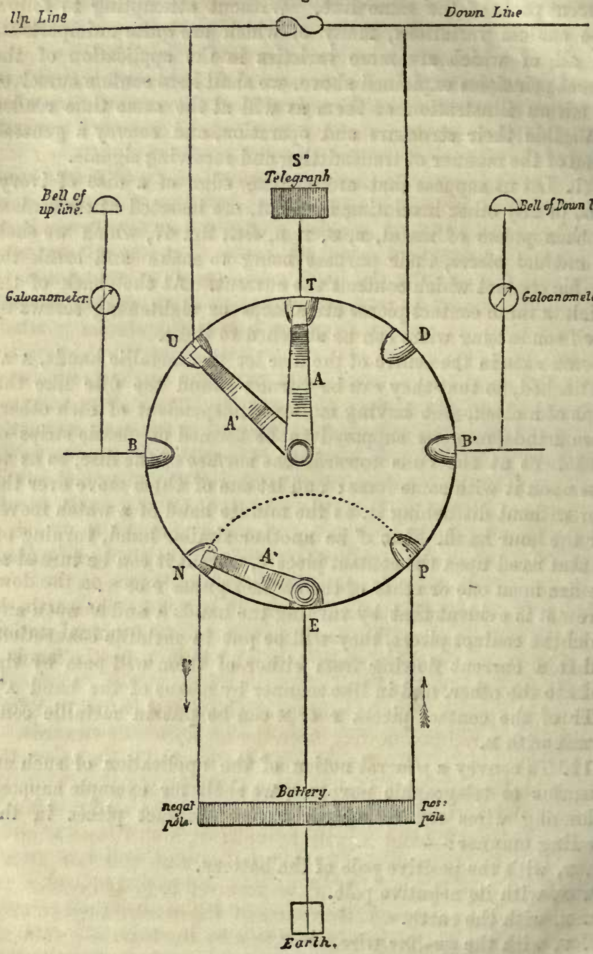
Now it is evident that by turning the hands A and A′ upon any two of the contact pieces, they will be put in metallic connection, so that a current flowing from either of them will pass by the hands to the other, and in like manner by means of the hand A″, either of the contact pieces P or N can be put in metallic connection with E.

112. To convey a general notion of the application of such an apparatus to telegraphic purposes, we shall for example suppose conducting wires connecting the several contact pieces in the following manner:—

1. P, with the positive pole of the battery.
2. N, with its negative pole.
3. E, with the earth.
4. U, with the *up-line* wire.
5. D, with the *down-line* wire.
6. B, with a bell or alarum.

It may be necessary to state here that it is customary to call the wire which proceeds to the chief terminal station of a line the *up wire*, and that which proceeds to the secondary terminal station the *down wire*. Thus, if a line of telegraph be extended between

Fig. 47.




London and Dover, the wire which would connect London with any intermediate station would *at that station* be the *up wire*, and the wire which would connect it with Dover would be the *down wire.*

The manner in which the current arriving at any station is made to ring a bell or alarum at that station, will be explained hereafter.

In explaining the manner in which the agent at a station is enabled to control a current by means of the commutator, two cases are to be considered—first, when he desires to transmit signals; and, secondly, when he expects to receive them.

In the former case, he takes the current from his own battery; in the latter, he receives it on its arrival by the up or down line wire.

We shall first consider the case in which he desires to transmit signals.

113. *To transmit a current on the up line only.*—Let the hand A″ be placed on N, A on P, and A′ on U. The negative pole N of the battery being then in connection with the earth E by the hand A″, and the positive pole P in connection with the up wire U by the hands A and A′, while the up wire itself at the station at which it arrives is in connection with the earth, the current will flow from P by A and A′ along the up wire to the station at which the wire goes to the earth.

114. *To transmit a current on the down line only.*—Let A″ and A be placed as before, and let A′ be moved to D. The current will then flow on the down line, as may be explained in the same manner.

115. *To transmit a current along the entire line from terminus to terminus.*—Let A′ be turned upon U, and A upon N, and let two similar hands at the back of the disc be at the same time turned upon P and D, the hand A″ being removed from both N and P. In that case, the current will flow from the positive pole P along the hands at the back of the disc to D, and thence on the down wire to the terminal station, where it will take the earth, by which it will pass to the earth plate at the up terminal station, and from thence by the up wire to U, and from U by the hands A′ and A to the negative pole N.

Thus it appears that it will pass along the entire line from terminus to terminus, flowing from the up station downwards.

116. *To reverse the direction of the current.*—To accomplish this, it is obviously sufficient to reverse the connections with the poles of the battery. Thus, if the current be transmitted on the up line only, the hand A′ will be upon U, A on P, and A″ on N, when, as already explained (113), the current will flow from U towards the up station. If A″ be removed to P, and A to N, the direction will be reversed, the course of the current then being as follows:—From the positive pole P to E by the hand A″; from the earth E to the earth plate at the upper station; from that to the up wire; from thence to U, and from U by A′ and A to N.

Thus, by alternately moving the hands A″ and A between the contact pieces P and N, the current may be changed from one direction to the other on the up wire as often and as rapidly as may be desired.

The same reversion may be made in exactly the same manner on the down wire, if the hand A′ be turned upon D.

The reversion may be made with equal facility and rapidity if the current be established along the entire line by merely interchanging the position of the hands directed upon P and N, as described in 115.

117. *To suspend and transmit alternately the current during any required intervals.*—Whether the current be established on the up line or on the down line, or on both, this is easily accomplished by removing any one of the hands from the contact piece on which it rests, and restoring it to its place after the required intervals. When it is withdrawn, the current is suspended; when restored, the current is re-established. The intervals of such suspension and transmission may be as long or as short as may be desired. They may be equal or unequal. They may succeed each other with any degree of rapidity whatever. Thus there may be ten thousand intervals of suspension and ten thousand of transmission in a minute. The instantaneous character of the propagation of the electric fluid already noticed will sufficiently explain this.

118. Having thus explained how the agent controls the current in transmitting signals to a distant station, we shall now show how he treats the current which arrives from a distant station, so as to allow it to produce before him the intended signals.

The current must arrive either by the up wire or by the down wire, and therefore at either of the contact pieces, U or D.

119. *To make the arriving current give the alarm.*—When the agent at a station is not engaged in transmitting signals, he must always be prepared to receive them. A contrivance called an alarum is provided, to give him notice when signals are about to be transmitted. The alarum, which will be fully explained hereafter, is an apparatus so constructed, that whenever the current passes through it, a bell is rung, by which the attention of the agent is called.

The contact piece B is here supposed to be connected with a wire leading to such an apparatus.

When not engaged in transmitting signals, the agent connects both the up and down wires with his alarum. To accomplish this, he turns A′ upon U, and A upon B. The contact piece B being supposed to be connected with the wire which enters the alarum, the wire which issues from it is connected with B′. Two hands, which are behind the disc, are placed one on B′ and the other on D. In this case, if a current comes down the line to U, it will pass by the hands A and A′ to B, and thence through the alarum wire to B′, whence it passes by the hands at the back of the disc to D, and thence along the down wire.

If, on the other hand, the current arrive by D, it passes in the same manner through the alarum to U, and so along the up wire.

From whatever part of the line the current may be transmitted, whether on the up or the down line, it must therefore pass through the alarum, and give notice.

120. In some cases a station is provided with two distinct alarums, one for the down and the other for the up line, having different tones, so that the agent, on hearing them, knows from which direction the signals are about to come.

In that case the wire of the up line alarum is attached to B, and that of the down line to B′, the wires which issue from the two alarums being always in such case connected with the earth.

When the agent is not engaged in transmitting, he places the hands A′ and A on U and B, and the hands behind the disc on D and B′. If a current arrive by U, it passes by B through the alarum to the earth, and gives notice. If it arrive by D, it passes in like manner through the alarum B′ to the earth, and gives notice.

It is, however, more usual to have a single alarum at each station, acting as above described.

The connections being so arranged that the current shall pass along the entire line from terminus to terminus, all the alarums at all the stations will be rung the moment the current is transmitted. General notice is therefore given that a dispatch is about to be sent from some one station along the line to some other.

121. It is necessary, however, to inform the agents at each station of the place from whence the dispatch is about to be sent, and the place to which it is to be addressed. To learn this, the agent transfers the connections from the alarum to his telegraphic instrument. This is accomplished by removing the hand A from B to T, and connecting the wire coming from the telegraphic instrument by the hands at the back of the disc with D. By this change the current passes from U to T, from T through the telegraphic instrument to D, and from thence down the line. The signals transmitted appear upon the telegraphic instrument, informing the agent whence the dispatch will come, and where it is desired to transmit it.

122. If he find that it is not to be addressed to himself, his arrangements will depend on the position which his own station holds in relation to the two stations between which the dispatch is about to be transmitted. If his station lie between them, he

turns the hands A and A′ upon the contact pieces U and D, so as to allow the current to pass between the up wire and the down wire, along the hands without interruption, and also without spending any part of its force in needlessly working his telegraphic instrument.

123. If he find that the dispatch is intended for himself, and that it proceeds from a station on the up line, for example, he places the hand A′ upon U, A upon T, and by the two hands behind the disc he connects the wire issuing from the instrument with E. By this arrangement, the current arriving at U passes by the hands A′ and A to T, thence through the telegraphic instrument to E by the hands behind the disc and to the earth.

In this case the course of the current is limited to the part of the line wire which is included between the station from which it is transmitted and that to which it is addressed. By connecting the telegraphic instrument with the earth by E, the down line wire is free; so that while the up line wire is employed in conveying the dispatch in question, other dispatches may be transmitted between any stations on the down line.

124. If we express for example the chief terminal station by S, and the series of stations upon the line proceeding from it downwards by $S_1$, $S_2$, $S_3$, $S_4$, &c., we can conceive various dispatches to be *at the same time* transmitted between them by the arrangement here explained, being made at each station which receives a dispatch. Thus, if S sends a dispatch to $S_1$, and $S_1$ cuts off its communication with the down wire by putting its telegraphic instrument in connection with the earth, the current transmitted from S stops at $S_1$. A dispatch may therefore be at the same time sent between $S_2$ and $S_3$, another between $S_4$ and $S_5$, and so on.

Thus, the same line of conducting wire may be at the same time engaged in the conveyance of several dispatches, the only limitation being that when a dispatch is being transmitted between two stations, no other dispatch can at the same time be transmitted between any of the intermediate stations.

It follows from this as a necessary consequence that if, as generally happens in thickly peopled tracts of country, the terminal and one or two of the most populous of the intermediate stations keep the telegraph in constant work, separate and independent wires, and instruments must be provided to serve the secondary intermediate stations, just as upon railways, second and third-class trains are provided to serve those lesser stations on the line, which are passed by the first-class trains without stopping.

Every great telegraphic line presents an example of this. Thus upon the Dover line separate wires and instruments are appropriated to the transmission of dispatches between the terminal stations, London and Dover, and the intermediate stations, Tonbridge, Ashford, and Folkestone. The conducting wire passes through the telegraph offices at these three intermediate stations, but does not enter any of those of inferior importance, such as Godstone, Penshurst, Marden, Staplehurst, &c., to the service of which other conducting wires and instruments are appropriated.

125. Since, however, telegraphic communication must be provided between *all* the intermediate stations, and since the chief wires passing the chief intermediate stations do not enter the secondary ones, it follows that the wires of the secondary stations must be carried not only to the terminal stations, but also through all the chief secondary stations. Thus the wires, which pass through the stations of Godstone and Penshurst, must also pass through those of Tonbridge, Ashford, and Folkestone, since otherwise there could be no communication between the latter and the former.

From what has been already explained, it will be understood that every two secondary stations along the line can communicate at the same time with each other, no stations being compulsorily silent, except such as may lie between two communicating ones. To illustrate this, let us suppose the secondary stations from terminus to terminus of the line to be expressed by the small letters, and the chief stations, terminal and intermediate, by the capitals, in the following order:

A, *b*, *c*, *d*, *e*, F, *g*, *h*, *i*, K, *l*, *m*, *n*, O.

Now, by the secondary wires A and *b*, *b* and *c*, *c* and *d*, and so on, may at the same moment hold communication. But if A and *d* communicate, *b* and *c* can communicate neither with each other, or with any other station. They are compulsorily silent. In like manner, if A and *m* communicate, *b*, *c*, *d*, *e*, *g*, *h*, *i* and *l* are all compulsorily silent.

Hence it will be apparent how necessary it is to put chief intermediate stations like F and K on the primary wires, since if they could communicate with A and O only by the secondary wires, frequent interruptions to the communications of all the secondary stations with each other would take place.

It will be also apparent that on lines of great intermediate business, a third or even fourth system of wires would be necessary.

This will render it easily understood why such a multiplicity of wires are seen stretching along the parts of the lines near London.

Lines of telegraph, like lines of railway, often have branches which are connected either with the primary or secondary wires of the main line, or with both, according to their importance. For example, on the main line between London and Dover, there are branches which go to Maidstone on the one side, and to Tonbridge Wells on the other. Sometimes these branch wires are provided with means of connection with the main line wires, so that the stations on the main line can communicate *directly* with those on the branch line. Sometimes no such connection is provided, and a dispatch from the main line must be repeated at the branch station. This is a defect which ought never to be allowed to remain, inasmuch as simple and efficient commutators may always be provided for connecting the branch and main lines, which in the telegraph play a part similar to the *switches* by which trains are turned from the main to the branch line, or *vice versâ*.

It will be evident from what has been said that a dispatch transmitted upon the secondary line of wires may be delivered at the same time at all the stations from terminus to terminus along the line, or it may be allowed to pass any one or more stations without entering them, by the mere management of the commutators provided at the stations severally.

126. In what has been said, we have adverted to signals produced by the current, without explaining the nature of those signals, or the particular means by which they are produced, because all the circumstances attending their transmission from station to station, which have been explained, are quite independent of the particular character of the signals, and the way of producing them. We shall hereafter explain the character of the signals which are used, and the instruments by which they are produced.

From all that has been stated meanwhile, it may be inferred generally that by the commutating apparatus which has been described above, or by any of the endless variety of equivalent contrivances which telegraphic inventors have proposed, any of the following effects may be produced by an agent at any station, at which a current arrives:—1. Such a current may be made to pass through the alarum, and give notice to the agent of its arrival. 2. It may be made to pass through the instrument and give signals. 3. It may be made to pass the station and continue its course along the line without affecting any part of the telegraphic apparatus at the station. 4. If it pass through the alarum, or through the instrument, it may be turned into the earth, and so be prevented from going further along the line. 5. If it pass through the alarum or through the instrument, it may after leaving them be directed along the line, so as to continue its course to the other stations below or above that at which it is supposed to arrive.

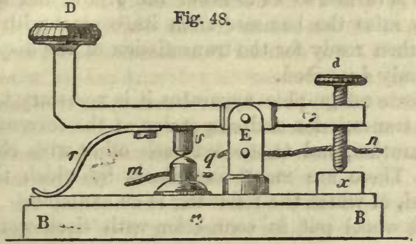
127. In some forms of telegraph, the system of signs transmitted to a distant station depends entirely upon the current being alternately suspended and transmitted for longer and shorter intervals, and this succession of long and short intervals, variously combined like the notes in music, is converted into a sort of telegraphic language, which by practice is expressed and understood by the

agent with as much facility and promptitude as ordinary written or spoken language.

128. In such forms of telegraph, the alternate suspension and transmission of the current is produced by a commutator, which has the form of the key of a pianoforte and is played upon in a very similar manner by the agent who transmits the dispatch.

One of the forms of these keys and the mechanism connected with it, is represented in fig. 48. It is fixed upon a wooden block

Fig. 48.




B B. The key plays upon a centre E. To the lower side of the longer arm (E D) is attached a projecting piece of metal *v*, called the HAMMER, under which is a fixed piece of metal of corresponding form and magnitude called the ANVIL.

The action of the key upon the current is the same precisely as that already described (117) which is produced by the alternately removing and restoring the hand to the contact piece in fig. 47. The hammer in the present case represents the hand, and the anvil the contact piece. One of the line-wires *m*, is attached to the anvil, and the other *n* to the metallic support E of the hammer and key. When the hammer is in contact with the anvil, the current passes, and when it is raised from that contact, the current is suspended.

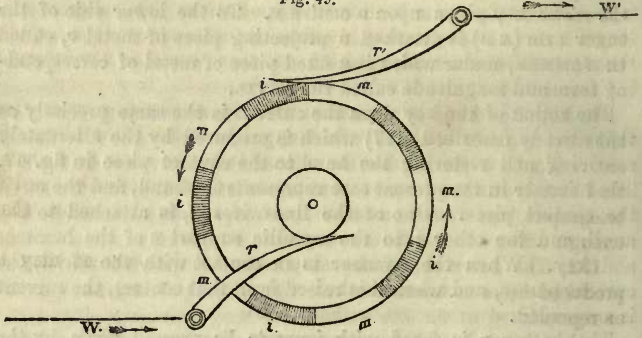
The button D is faced with ivory to be pressed down by the finger, and the screw *d* passing through the short arm of the key is pressed upon the block *x* by the reaction of the spring *r*, when the key is not pressed down by the finger on D. The hammer *v*, and anvil *q* are both faced with platinum to prevent oxydation, which would obstruct that complete metallic contact which is necessary to ensure the transmission of the current.

An expert manipulator can work the key D with as much celerity and correctness as can a performer on the pianoforte and can express in that way in telegraphic language any dispatch which is placed in manuscript before him, so as to transmit it to any distant station. This will be explained more fully hereafter. When no dispatch is being transmitted from the station at which the key is placed, it is necessary to leave a free passage for the current along the line-wires *m n*. To effect this, the screw *d*, which passes through the short arm of the key, is turned so as to raise the short arm, and consequently lower the arm E D until the hammer *v* is brought into permanent contact with the anvil *q*. When that takes place, the metallic continuity between *m* and *n* will be established, and the current will flow without interruption on the line-wire. Whenever it is desired to transmit a dispatch, the screw *d* is turned so as to lower the arm *d*, and to raise E D, and thus to raise the hammer from its contact with the anvil. The key is then ready for the transmission of the dispatch in the manner already described.

129. In some telegraphic apparatus it is necessary to make the intervals of transmission and suspension of the current absolutely equal in duration, and to succeed each other with chronometric regularity. There are many expedients by which this can be accomplished, of which the following is an example.

A metallic wheel put in connection with clock-work, so as to

Fig. 49.




receive a regular motion of rotation, has its edge divided into equal parts by pieces of ivory, or some other non-conductor inlaid upon it, as represented in fig. 49, where *m* represents the metal, and *i* the ivory. A metallic spring *r′* connected with one end of the conducting wire W′, presses constantly upon its edge; and another *r* connected with the other end of the wire W, presses constantly on the metallic axle of the wheel which is otherwise insulated.

Now, if the wheel be supposed to have an uniform motion of revolution, the alternate divisions of ivory and metal on its edge will pass in succession under the spring *r′*, while the spring *r* will be in constant metallic contact with the axis. If a current flows on the wire W, it will be transmitted by the spring *r* to the axle, and thence by the metal of the wheel to $r'$, when $r'$ is in contact with any of the metallic parts $m$ of the edge of the wheel, but will be suspended while it is in contact with the ivory parts $i$ of the edge.

If the wheel, being impelled by clock-work, be moved at such a rate that each of the divisions marked $m$ and $i$ shall move under the spring in one second, the current will be transmitted and suspended also during intervals of one second. It will in fact be subject to a regulated pulsation, the rate of which will be controlled and determined by the horological mechanism which impels the wheel.

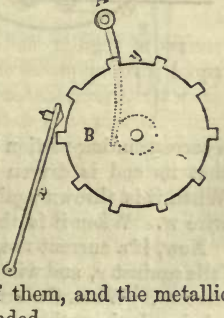
130. In some cases, the motion to be imparted to the wheel is not either regular or continuous. In such cases, it may be moved either directly by hand, or by a strap, or even by clock-work, which is subject to a check which will suspend it at certain positions of the wheel. In all these cases the pulsations of the current in number, length, and continuance, are governed by the motion imparted to the wheel.

131. As the suspension and transmission of the current are instantaneous upon the breach and re-establishment of the metallic contact of the spring $r'$ and the wheel, there is no practical limit to the rapidity which can be given to its pulsations. The wheel may be turned, for example, so that 500 divisions of its edge may pass under the spring $r'$ in a second, in which case there would be 250 intervals of transmission, and 250 intervals of suspension in a second.

It might perhaps be imagined that in so short an interval of time the current could not be stopped or established along the entire length of the conducting wire. It has however been shown that even with the longest continuous wires, practically used in telegraphs, the ten-thousandth part of a second is more than enough either to establish or stop the current.

132. The intervals of the suspension of the current may be produced by a common toothed-wheel, as represented in fig. 50, without ivory or other inlaid non-conducting matter. In this case, a piece of wedge-shaped metal connected with the up line wire is attached to the under side of a wooden lever, while the axle of the wheel is kept in constant metallic connection with the down wire. When a tooth of the wheel comes against the metal attached to the lever, metallic contact is established, but when the metal falls between the teeth, and the surface of the wooden lever rests on one of them, and the metallic contact being broken, the current is suspended.

Fig. 50.

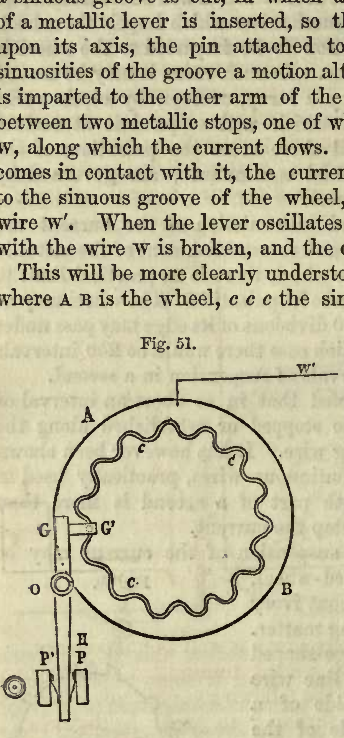


It is evident that during each revolution of the wheel there will be as many pulsations of the current as there are teeth, and since the rotation of the wheel may be as rapid as may be desired, and the teeth as numerous, there is no practical limit to the possible rapidity of these pulsations.

133. Another contrivance, by which pulsations are imparted to the current, consists of a metallic wheel around the face of which a sinuous groove is cut, in which a pin, projecting from the arm of a metallic lever is inserted, so that when the wheel is turned upon its axis, the pin attached to the lever receives from the sinuosities of the groove a motion alternately right and left, which is imparted to the other arm of the lever. This latter arm plays between two metallic stops, one of which is connected with the wire W, along which the current flows. When the arm of the lever comes in contact with it, the current is transmitted on the lever to the sinuous groove of the wheel, and from thence to the line-wire W′. When the lever oscillates to the other side, the contact with the wire W is broken, and the current is interrupted.

This will be more clearly understood by reference to the fig. 51, where A B is the wheel, *c c c* the sinuous groove, G O H the lever playing on the axis O. From G, a short projecting piece, G G′, passes in front of the wheel across the groove, and from this piece a pin projects, which enters the groove. The arm H plays between two stops, P and P′, provided with springs to ensure the contact with the lever. The stop P is connected with the conducting wire W, and the groove *c* is connected with the wire W′. When the wheel is turned, the pin at G′ is driven by the sinuosities of the groove alternately right and left, by which a corresponding motion is imparted to the arm H of the lever, so that its end is driven alternately against the stops P and P′. When it is thrown against P it is in metallic connection with the wire W. When it is thrown against P′ that connection is broken.

Fig. 51.

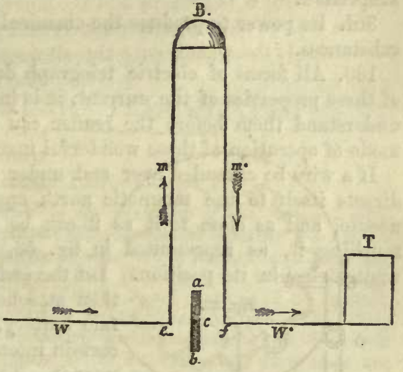



Now, if a current flow along P, it will pass to the lever when H falls against P, and will pass by the lever and the groove *c c* to the wire W′. When the arm H is thrown against P′, the contact with P being broken, the current is suspended. Thus, as the lever is made to oscillate between P and P′, by the motion of the wheel and the action of the sinnous groove, the current will be alternately transmitted and suspended, and will, in fine, receive a succession of pulsations corresponding exactly with the sinuosities of the groove. Thus, if there be sixty undulations of the groove in the circumference of the wheel, the current will receive sixty pulsations in one revolution of the wheel, and if the wheel revolve at the rate of sixty revolutions per minute, the current will have 3600 pulsations per minute.

134. An expedient has been sometimes adopted in telegraphic apparatus for diverting the electric current from its direction, which differs in principle from the commutator, and which depends on the tendency of the current to follow the shortest and widest route open to it between one point and another.

Let W, fig. 52, be the line-wire, B the bell-apparatus, and T the telegraphic instrument. The line-wire is bent upwards in the direction *m* to the bell B, and then downwards, and by *m′* and W′ to the telegraph T. The current would, according to this arrangement, first pass by the wire *m* to the bell B, which it would ring, and then by the wire *m′* W′ to the telegraph T. If the dispatch were then transmitted, the current constantly passing through B during its transmission, the bell would be constantly ringing, which would be inconvenient as well as unnecessary.

Fig. 52.




This is prevented, and the current transmitted directly to T, without passing through B, by the following very simple expedient.

A thick piece of metal, *a b*, turns on an axis *c*, so that when it is placed in the horizontal position, the ends *a* and *b* are brought into close contact with the conducting wire at *e* and *f*. The current, on arriving at *e* divides itself into two parts, one going by *a b* to *f*, and thence to T, and the other as before, by *m*, through the bell. But as *a b* is much shorter and thicker than the wire *m m′*, the greater part of the current will go by *a b*, and the part which passes along *m m′* will be too inconsiderable to exercise the force necessary to ring the bell.

The agent, therefore, at the station, receiving the dispatch, being warned by the bell that the agent at the station s is going to send a dispatch, turns the piece *a b* into the horizontal position, and the bell ceases to ring, the telegraph T receiving the dispatch.

135. The manner in which the pulsations of the current are produced, controlled, and regulated, by the operator at the station s″ being understood by these examples and illustrations, it will next be necessary to show how they are made to produce signals at the station to which the dispatch is transmitted, by which the operator or observer there can be enabled to understand and interpret the communication.

The effects of the current which have been found most convenient for this purpose are—

1st. Its power to deflect a magnetic needle from its position of rest, and to throw it into another direction.

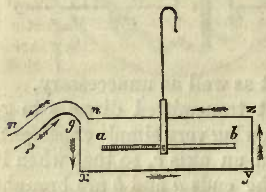
2nd. Its power to impart temporary magnetism to soft iron, this magnetism suddenly deserting the iron when the current is suspended.

3rd. Its power to produce the chemical decomposition of certain substances.

136. All forms of electric telegraph depending on one or other of these properties of the current, it is indispensably necessary to understand them before the reader can hope to comprehend the mode of operation of these wonderful instruments.

If a wire be extended over and under a compass-needle which directs itself to the magnetic north and south, parallel to the needle, and as close to it as it can be placed without actually touching it, as represented in fig. 53, the needle will remain undisturbed in its position. Let the ends *p* and *n* of the wire be then attached to the poles of a voltaic battery, so that a current of a certain intensity shall be transmitted upon it. The moment the current is established upon the wire, the magnetic needle *a b* will be thrown out of its usual direction, and instead of pointing north and south, it will point east and west.

Fig. 53.




If the direction of the current upon the wire be reversed, the direction of the deflexion of the needle will be reversed.

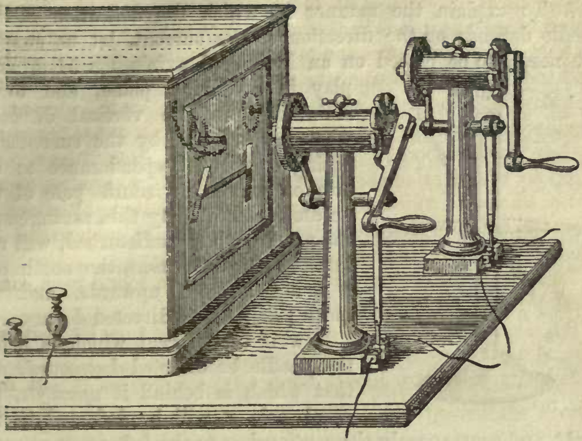


Fig. 72.—FRENCH STATE TELEGRAPH.

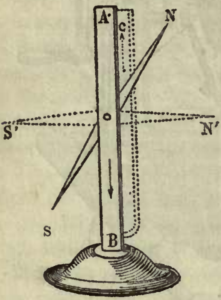
# THE ELECTRIC TELEGRAPH.

## CHAPTER VI.

137. Relation of the deflection to the direction of the current.—138. Galvanometer or multiplier.—139. Method of covering the wire.—140. Method of mounting the needle.—141. Method of transmitting signals by the galvanometer.—142. How the current may produce a temporary magnet.—143. Electro-magnet constructed by Pouillet.—144. Electro-magnets formed by two straight bars.—145. They acquire and lose their magnetism instantaneously.—146. Magnetic pulsations as rapid as those of the current.—147. How they are rendered visible and counted.—148. Extraordinary celerity of the oscillations thus produced.—149. They produce musical sounds by which the rate of vibration may be estimated.—150. How the vibrations may impart motion to clock-work.—151. Their action on an escapement.—152. How the movement of one clock may be transmitted by the current to another.—153. How an electro-magnet may produce written characters on paper at a distant station.—154. How the motion of the hand upon a dial at one station can produce a like motion of a hand upon a dial at a distant station.—155. How an agent at one station can ring an alarum at another station.—156. Or may discharge a gun or cannon there.—157. Power of the bell or other signal not dependent on the force of the current.—158. Mechanism of telegraphic alarum.—159. Various alarums in telegraphic offices.—160. Magneto-electricity.—161. Method of producing a momentary magneto-electric current.—162. Application of an electro-magnet to produce it.

137. To explain the manner in which the deflection of the needle depends on the direction of the current, let us suppose the needle to be placed on an horizontal axis o, fig. 54, so as to play in a vertical plane, and to be maintained in the vertical direction when not affected by the current, by giving a slight preponderance to the arm on which the south pole of the needle is placed. By this arrangement the needle, when undisturbed, will rest in the vertical position, the north pole N being directed upwards, and the south pole S being directed downwards.

Fig. 54.




Now if the current which is before the needle be directed *downwards* and that which is behind it *upwards*, the *north* pole N will be deflected to the *right*, and consequently the *south* pole S to the *left*, as represented in the figure. But if the direction of the current be reversed so that *before* the needle, it shall be directed *upwards* and *behind* it *downwards*, the north pole N will be deflected to the left and the south pole S to the right.

If the intensity of the current be great, and the preponderance given to the lower arm of the needle small, the deflective force of the current will be sufficient to throw the needle completely at right angles to its position of rest, that is, to give it the horizontal direction; but it is important to observe, that no greater intensity of the current can affect it further. The north pole, for example, cannot be deflected downwards, or the south pole upwards. In fine, the needle cannot be more affected by any increase of force of the current after it has once been thrown into the horizontal direction.

If the intensity of the current be insufficient to throw the needle into the horizontal direction, it will nevertheless take a position intermediate between that and the vertical direction at which it will rest. Its deflection from the vertical will be more and more considerable as the current is more intense, and certain mathematical conditions have been discovered by which the relative intensity of the current may be determined by the amount of the deflection of the needle which it produces.

138. It is evident that the sensibility of the needle will be so much the greater as the preponderance of the arm S is diminished and the intensity of the current increased. An expedient has, however, been ingeniously contrived, by which the most feeble current can be made to affect the needle. This is accomplished by

winding the wire which carries the current several times round the needle, each coil being still parallel to the needle. By this contrivance, each successive coil of the wire produces a separate effect upon the needle, and if there be fifty such coils passing successively before and behind the needle, each portion of the wire thus carrying the current producing an independent deflecting force, there will be a total deflecting force an hundred times greater than that which a single portion of the wire, passing once over or under the needle would produce.

In this manner the deflecting power of the most feeble current may be so *multiplied* as to produce upon the needle as powerful an effect as would be produced by a current of great intensity.

An apparatus consisting of wire thus coiled round a magnetic needle is called a MULTIPLIER, inasmuch as it multiplies the deflecting power of the needle. It is also called a REOSCOPE, or REOMETER,* and sometimes a GALVANOSCOPE, or GALVANOMETER, inasmuch as it indicates the presence, and by certain arrangements, measures the intensity of a galvanic or voltaic current.

139. When the conducting wire is thus coiled round a needle, it is necessary that it should be covered or coated by some substance which is a non-conductor of electricity, since otherwise the coils being necessarily in contact one with another, the current, instead of following the continuous thread of wire, would pass from coil to coil. In such cases, therefore, the wire is wrapped with silk or cotton, which being a non-conductor, confines the current within it just as water would be included in a pipe.

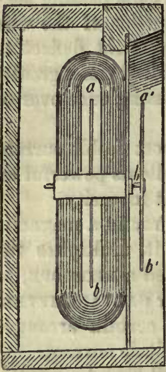
140. As the wire coiled in the manner above-described, and the frame which carries it, would prevent the play of the needle from being easily and conveniently observed, the needle included within the frame is fixed upon the axis which supports it, so that the axis turns with it. This axis passes through the side of the frame, on which the wire is coiled, and upon the end of it which projects beyond the frame a hand is fixed, so as to be parallel to the needle, the play of which will necessarily correspond with that of the needle. This hand plays upon a sort of dial, by which its deviations to the right or to the left, from its position of rest are indicated.

This will be more clearly understood by reference to fig. 55 (p. 196), which represents a section of the mounting of the needle, the coil of wire and their appendages, made by a vertical plane through the axis of the needle. The needle within the coil is represented at *a b*, in its position of rest. The axis of the needle

* From two Greek words, ρεος (reos) a current, and μετρον (metron) a measure.

passing through the frame supporting the coil, and through the dial plate, supports in front of the dial the hand *a′ b′*, which is fixed upon the axis in a position parallel to the needle *a b*, so that it must play before the dial in a manner corresponding exactly with the play of the needle *a b* within the coil.

Fig. 55.



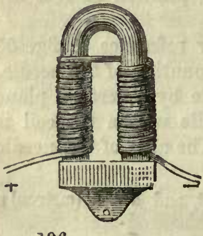

141. In order to govern the play of the needle, it is necessary that the agent at the station from which the signal is transmitted should have the power, 1st. To suspend and transmit the current at the receiving station; and 2nd. To change its direction upon the conducting wire. The former is necessary, to enable him to bring at all times the needle to its position of rest; and the latter, to deflect it to the right or to the left, according to the exigencies of the telegraphic communications.

The general principle on which these changes in the flow and direction of the current are effected, has been already explained (111). It is easy to imagine, that by very simple mechanism the movement of a lever or arm may make or break the contact of the conducting wires, so as to transmit or suspend the current at pleasure. Also by a simple motion of such an arm the hands, A and A″, fig. 48, or any equivalent pieces, may be moved from P to N and from N to P, so as to reverse the current upon the wire to which the arm A′ is directed.

If then an agent at the station, S″, for example, be provided with any means of suspending or reversing the current which passes along the wire, between S and S″, he can at will bring a magnetic needle, mounted at S, to its position of rest, that is, to the vertical position, by suspending the current or deflect it to the right, by causing the current to flow in one direction on the conducting wire, or to the left, by reversing the direction of the current.

The particular manner in which these several operations subserve to telegraphic purposes will be presently explained.

Fig. 56.




142. To explain the manner in which the electric current can impart temporary magnetism to soft iron, let us suppose a copper wire wrapped with silk, to prevent the metallic contact of contiguous convolutions, to be coiled round a rod of soft iron, bent into the form of a horse-shoe, as represented in fig. 56, care being taken, that in carrying the wire from one arm to the other, the

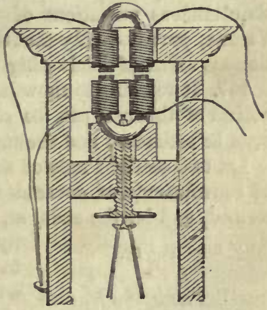
direction of the convolutions shall be the same as if the coils had been continued round the bend.

So long as no electric current passes along the convolutions of the wire the horse-shoe will be free from magnetism. But if the ends of the wire, marked + and —, be put in connection with the poles of a voltaic battery, so that a current flow round its convolutions, the horse-shoe will instantly become a magnet, and will be so much the more powerful as the current is more intense, and the coils more multiplied.

If an armature loaded with a weight be presented to the ends of the horse-shoe while the current passes on the wire, it will adhere to them, and the weight, if not too great, will be supported.

143. In 1830 an electro-magnet of extraordinary power was constructed under the superintendence of M. Pouillet, at Paris. This apparatus, represented in fig. 57, consists of two horse-shoes, the legs of which are presented to each other, the bends being turned in contrary directions. The superior horse-shoe is fixed in the frame of the apparatus, the inferior being attached to a cross-piece which slides in vertical grooves formed in the sides of the frame. To this cross-piece a dish or plateau is suspended in which weights are placed, by the effect of which the attraction which unites the two horse-shoes is at length overcome. Each of the horse-shoes is wrapped with 10,000 feet of covered wire, and they are so arranged that the poles of contrary names shall be in contact. With a current of moderate intensity the apparatus is capable of supporting a weight of several tons.

Fig. 57.



144. It is found more convenient generally to construct electro-magnets of two straight bars of soft iron, united at one end by a straight bar transverse to them, and attached to them by screws, so that the form of the magnet ceases to be that of a horse-shoe, the end at which the legs are united being not curved but square. The conductor of the heliacal current is usually a copper wire of extreme tenuity.

145. In whatever form these magnets are constructed, the circumstance which in their telegraphic use is of most importance to notice, is that if proper conditions be observed in their preparation, their acquisition of the magnetic virtue upon the

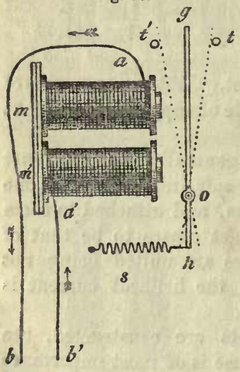
establishment of the current, and their loss of it upon the suspension of the current, are, for all practical purposes, instantaneous. The moment the extremities of the wire coiled round the horse-shoe are put into connection with the poles of the battery the horse-shoe becomes a magnet, and the moment the connection with the battery is broken it loses the magnetic virtue.

146. It has been already shown, that by means of very simple expedients, the current may be interrupted hundreds or even thousands of times in a second, being fully re-established in the intervals. The acquisition and loss of magnetism by the horse-shoe accompany these pulsations with the most perfect and absolute simultaneity. If the pulsations of the current be produced, at the rate of a thousand per second, the alternate presence and absence of the magnetic virtue in the horse-shoe will equally be produced at the rate of a thousand per second. Nor are these effects in any way modified by the distance of the place of interruption of the current from the magnet. Thus, pulsations of the current may be produced by an operator in London, and the simultaneous pulsations of the magnetism may take place at Vienna, provided only that the two places are connected by a continuous series of conducting wires.

147. It remains to show how these rapid pulsations of the magnetism of the bar can be rendered sensible, and how they may even be estimated and counted.

Let two straight rods of soft iron be surrounded by a succession of convolutions of covered wire, such as has been already described, and let the ends, *m*, *m′*, fig. 58, of these rods be connected by a straight bar of soft iron, attached to them by screws and nuts. Let the wire, *a b*, proceeding from a distant station, s, be put in metallic connection with the extremity of the wire coiled upon the rod, *m*, and let the wire, *a′ b′*, connected with the extremity of the last convolution of the wire on the rod, *m′*, be put in metallic connection with the earth. If a current flow along *a b*, it will therefore circulate round the rods, *m* and *m′*, and will pass to the earth by the wire, *a′ b′*. So long as this current flows, the rods will be magnetic, and they will lose their magnetism in the intervals of its suspension.

Fig. 58.




Let *g h* be a light iron bar, supported on a pivot, at *o*, on which it is capable of playing, so that its arm, *o g*, may move freely to the right or left. Let $t$ $t'$ be two stops, placed a small distance to the right and left of its extremity, $g$, so as to limit the range of its play. Let $s$ be a spring attached to the extremity, $h$, by which that extremity will be constantly drawn to the left, and therefore the opposite extremity, $g$, thrown to the right against the stop, $t$. When the current is suspended, and the rods, $m$ $m'$, divested of magnetism, the lever yielding to the action of the spring, $s$, the end, $g$, will rest against the stop, $t$. But when the current passes on the wire, the rods, $m$ $m'$, becoming magnetic, will attract the arm, $o$ $g$, of the lever, and this attraction exceeding the force of the spring, the arm, $o$ $g$, will be drawn towards the electro-magnet, until it encounters the stop, $t'$, against which it will rest so long as the current continues to flow. But the moment the current is suspended, the bars, $m$ $m'$, suddenly losing their magnetism, the lever, $o$ $g$, is abandoned to the action of the spring, and it is again thrown back upon the stop, $t$, where it rests until the current is re-established.

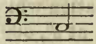
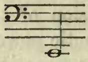
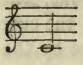
Let us suppose that an agent at the station, s, to which the wire, $a$ $b$, extends, and which may be at any distance, 500 miles for example, from s″, is supplied with any of the means which have been explained, by which he can at will control the pulsations of the current. When he causes the current to flow, he imparts magnetism to the bars, $m$ $m'$, and throws the lever, $o$ $g$, against the stop, $t'$. When he suspends the current he deprives the bars, $m$ $m'$, of their magnetism, and leaves the lever, $o$ $g$, to the action of the spring, $s$, by which it is thrown against the stop, $t$.

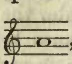
It appears, therefore, that with each pulsation which the current receives from the agent at s, the lever, $o$ $g$, at s″, 500 miles distant from him, will perform a vibration between the stops, $t$ and $t'$. As the transmission and suspension of the current, and also the acquisition and loss of the magnetic power, by the rods, $m$ $m'$, are both instantaneous, there is no practical limit to the velocity of the pulsations of the current and those of the magnetism alternately acquired and lost by the rods, $m$ $m'$. The oscillations of the lever, $o$ $g$, produced by these pulsations are limited, however, by the weight of the lever, the force of the spring, and the distance between the stops, $t$ and $t'$. The greater the weight of the lever, the force of the spring, and the distance between the stops, the slower will be the motion of the lever from $t$ to $t'$, produced by a current of given intensity. The greater the weight of the lever, and the distance between the stops, and the less the force of the spring, the slower will be the motion from $t'$ to $t$.

The stop, $t'$, is so placed as to prevent the absolute contact of the arm of the lever with the electro-magnet, but to allow it to approach the latter very closely. Absolute contact is to be avoided, because it is found that in that case the arm adheres to the magnet with a certain force after the current ceases to flow, but so long as absolute contact is prevented, it is immediately brought back by the spring, *s*, when the current is suspended.

148. It is evident, therefore, that the limit of the possible celerity of vibration to be imparted to the lever, *o g*, by the pulsations of the current will depend on the nice adjustment of the weight and play of the lever, and the force of the spring, *s*.

The velocity of oscillation, however, which can in this way be imparted to the lever, is such as can scarcely be credited without actually witnessing its effects. When that velocity does not exceed a certain limit the oscillations may be registered and counted, by causing the lever to give motion to the anchor of an escapement, connected with a train of wheel-work, by which a hand or index, moving on a graduated dial, is governed. But these oscillations are susceptible of velocities so great that it would be difficult to apply this expedient for counting them. M. Gustave Froment, of Paris, suggested and applied to this purpose with complete success, a method of ascertaining the velocity depending on the laws which govern the vibrations of musical strings.

149. It is well known that the pitch of any musical note is the consequence of the rate of vibration of the string by which it is produced, and that the more rapid the vibration the higher the note will be in the musical scale, and the slower the vibration the lower it will be. Thus the string of a pianoforte which produces the bass note  vibrates 132 times in a second, that which produces the note  vibrates 66 times in a second, and that which produces the note  vibrates 264 times per second.

On a seven octave pianoforte the highest note in the treble is three octaves above , and the lowest note in the bass is four octaves below it. The number of complete vibrations corresponding to the former must be 3520 ; and the number of vibrations per second corresponding to the latter is $27\frac{1}{2}$.

If, therefore, the lever, *o g*, have any rate of vibration more rapid than $27\frac{1}{2}$ vibrations per second, and less rapid than 3520 per second, it will produce by its motion some definite musical sound, and if the note formed upon a pianoforte, which is in unison with it, be found, the rate of vibration of the string producing that note, will be the same as that of the lever.

When it is stated that the vibrations imparted by the pulsations of the current to levers, mounted in the manner here described, have produced musical notes nearly two octaves higher than the highest note on a seven octave piano, tuned to concert pitch, it may be conceived in how rapid a manner the transmission and suspension of the electric current, the acquisition and loss of magnetism in the soft iron rods, and the consequent oscillation of the lever, upon which these rods act, take place. The string which produces the highest note, on such a piano, vibrates 3520 times per second. A string which would produce a note an octave higher would vibrate 7040 times per second, and one which would produce a note two octaves higher would vibrate 14080 times per second.

It may, therefore, be stated, that by the marvellously subtle action of the electric current, the motion of a pendulum is produced, by which a single second of time is divided into from twelve to fourteen thousand equal parts!

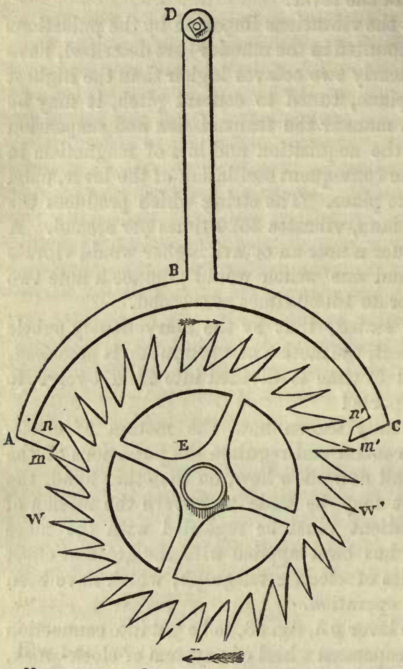
150. It has been already shown how the motion of clock-work may be applied to control and regulate the pulsations of the electric current. We shall now show how, on the other hand, the pulsations of the current may be made to govern the motion of wheel-work. This expedient must be regarded with the more interest inasmuch as it has been applied with the greatest effect in several of the varieties of electric telegraph, which have been proposed or brought into operation.

151. If we suppose the lever *g h*, fig. 58, to be put into connection with the anchor of the escapement wheel of a system of clock-work, it will be easy to see how that clock-work can be regulated by the pulsations of the electric current.

In fig. 59 (p. 202), W W′ is the escapement wheel which is constantly impelled by the force of a descending weight or mainspring in the direction of the arrows. The anchor A B C, of the escapement, is connected with an axis D, by the straight rod B D. This rod B D may be either the vibrating arm of a lever, such as *g h*, fig. 58, kept in oscillation by the current acting on an electro-magnet, or it may be connected with such a lever in any convenient manner, so as to oscillate simultaneously with it, and to have the extent of play necessary for the action of the pallets A and C of the anchor on the teeth of the escapement wheel.

When the anchor is not in a state of oscillation, a tooth of the wheel will rest upon one of its pallets, and the wheel and clock-work connected with it will be stopped. When the anchor moves from left to right, the tooth of the wheel, which was previously stopped by the upper surface $n'$ of the pallet C, is allowed to *escape*,

Fig. 59.




and in obedience to the power of the spring or weight, which moves the clock-work, it advances towards $m'$. Meanwhile the pallet A enters the space between two teeth of the wheel, one of which coming against its lower surface, it stops its motion. When the anchor moves back from right to left, the pallet C comes under the next tooth of the wheel. In this manner every movement of the anchor to the right lets a tooth, which was stopped by the pallet C, advance, and afterwards the pallet A stops the advance of another tooth, while every movement to the left lets the tooth stopped by A advance, and afterwards the pallet C stops the next tooth which advances on that side.

Thus each complete oscillation of the anchor, consisting of a motion to the right and a motion to the left, lets one tooth of the escapement wheel, and no more, pass.

Now if we suppose the pulsations of the current to impart to the anchor by the intervention of the electro-magnet and its appendages a motion of vibration, a tooth of the escapement wheel, and no more than one tooth, will pass the anchor for each pulsation of the current. If the current be suspended the movement of the escapement wheel and the clock-work connected with it will be also suspended, and when the pulsation of the current recommences, the oscillations of the anchor, and consequently the motion of the escapement wheel, and the clock-work connected with it, will also recommence.

152. If the pulsations of the current be regulated (as they may

be according to what has been already explained (129), by the pendulum of a clock at any station, the motion of the anchor of the escapement established at any other station to which the current is transmitted, will be synchronous with that of the pendulum of the clock which governs the pulsations of the current, and thus a regular motion may be imparted by one clock to another, provided that between them there be established a conductor, and the pendulum of the one clock regulates the pulsations of the current, which govern the movement of the anchor of the escapement of the other.

153. If the extremity of the lever, *o g*, fig. 58, carry a pencil, which presses upon paper, when the lever is drawn towards the electro-magnet, and if at the same time the paper is moved under the pencil with an uniform motion, a line will be traced upon the paper by the pencil, the length of which will be proportionate to that of the interval during which the lever *o g* is held in contact with the stop *t′*. Now as the agent at S can regulate this interval at will, by controlling the flow of the electric current, making that current act for a short interval if he desire to make a short line upon the paper, for a long interval if he desire to make a long line, and for an instant if he desire to make merely a dot, it will be understood how he can at will mark a sheet of paper at S″, 500 miles distant, with any desired succession of lines of various lengths or of dots, and how he may combine these in any way he may find suitable to his purpose.

We have here supposed the pencil attached to the end of the lever to be alternately pressed against the paper, and withdrawn from it by the motion of the lever. If, however, the paper be so placed that the lever shall oscillate parallel to it, the pencil presented to the paper will remain permanently in contact with it, and will trace upon the paper a line alternately right and left, whose length will be equal to the play of the end *g* of the lever, to which the pencil is attached. If while this takes place the paper be moved under the pencil in a direction at right angles to the line of its play, the pencil will trace upon the paper a zigzag line, the form of which will depend on the relation between the motion of the paper and that of the pencil. When the current is in this case suspended, the paper being moved under the pencil at rest, a straight line will be traced upon it.

Thus the paper will be marked either with a zigzag line, or a straight line according as the current is transmitted or suspended.

If the current be alternately transmitted and suspended during intervals of unequal length, at the will of the agent, at S, the paper at S″ will be marked by a line alternately zigzag and straight, the length of the zigzag and straight parts being varied at the will of the operator at S.

How these subserve to telegraphic purposes will be presently more fully explained.

154. In the same manner, if a toothed wheel, moved by the agent at S, produce a pulsation of the current by the passage of each successive tooth, these pulsations will produce simultaneous oscillations of the lever *o g*, at the station S″, and if these oscillations act upon the anchor of an escapement wheel attached to clock-work at S″, that wheel will be advanced in its revolution, tooth for tooth, with the wheel at S, and if each of these wheels govern the motions of hands upon dial plates, like the hands of a clock, the hand of the dial at S″ will have the same motion exactly as the hand on the dial at S, so that if at the commencement of the motion both hands point to the same figure or letter of the dial, they will continue, moving together, to point always to the same figures or letters.

Thus if the operator at S desire to direct the hand on the dial at S″, to the hour of 3 or 5, he will only have to turn the hand upon the dial, at his own station, to the one or the other of these hours.

It will presently also be apparent how important this is in the art of electro-telegraphy.

155. If the lever *o g*, fig. 58, be connected with the tongue of an alarum-bell, so that when *o g* is put into vibration the bell will ring, and will continue to ring so long as the vibration is continued, it is evident that the operator at S can, at will, ring a bell at S″, by producing pulsations of the current in any of the ways already described.

An operator at S″ may in like manner ring a bell at S.

By this mutual power of ringing bells, each operator can call the attention of the other, when he is about to transmit a dispatch, and the other by ringing in answer can signify that he is prepared to receive the dispatch, as already stated.

156. If the lever *o g* were in connection with the lock or other mechanism, by which the powder charging a cannon is fired, the operator at T could at will discharge a cannon at R, no matter what may be the distance of R from T.

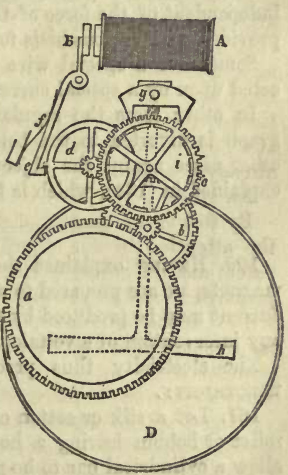
157. It will be observed that when a bell is rung, or any similar signal produced at the station S″, by means of an electric current transmitted from a distant station, S, it is not directly the force of the current which acts upon the object by which the signal is made. The current is only indirectly engaged, producing the result by liberating the mechanism which makes the signal and leaving the force which moves it free to act. Thus in the most usual case of a bell, it is acted upon while it rings, not by the

current, but by the force of a mainspring or descending weight, transmitted to the hammer or tongue in the same manner exactly as that in which the force of a mainspring or weight of a clock is transmitted to the striking apparatus. The current does nothing more than disengage a catch by which the motion of the wheel-work acted on by the mainspring or weight, is arrested. The catch once disengaged, the action of the current on the bell ceases, and the ringing is continued by the action of the mainspring or weight, and it may in like manner be stopped by the current again throwing the catch between the teeth of one of the wheels.

It will, therefore, be apparent that since the force which impels the bell is independent of the current, a bell of any desired magnitude may be acted upon by a hammer of any desired weight, without requiring any more force from the current than that which is sufficient to enable the electro-magnet to disengage the catch by which the mechanism of the bell is arrested.

158. Although the bell mechanism used for telegraphs differs in nothing which is essential from that of a common alarum clock, it may not be without interest to show one of the varieties of mechanism in practical use.

Fig. 60.




In fig. 60 is given a view of the bell mechanism, as used on the telegraphic line of the South-Eastern Railway Company.*

A is the electro-magnet.

B its armature.

B *e* a lever attached at the upper end to the armature, and having at the lower end a catch, *e*, which when the armature is not attracted towards the magnet is pressed by a spring, *f*.

*d* a wheel having a tooth in which the catch *e* is engaged by the pressure of the spring *f*, when the armature B is not attracted towards the magnet, but which is liberated from the catch *e*, when the armature B is drawn towards the magnet.

*a* a cylindrical box containing a strong mainspring, by which the train of wheelwork is kept in motion so long as the catch *e* is not engaged in the tooth of the wheel *d*.

* Elect. Tel. Manip., p. 23.

The actual contact of the armature B with the poles of the electro-magnet is prevented by two small ivory knobs screwed into the surface which is presented to the magnet. The play of the armature B is so limited that the catch *e* shall be just disengaged from the tooth of the wheel *d*, when the ivory knobs come into contact with the poles of the magnet.

When the wheel-work is liberated by the magnet withdrawing the catch *e* from the wheel *d*, the mainspring in the cylindrical box *a* causes the toothed wheel attached to the box to revolve. This wheel drives a pinion on the axle of the wheel *b*; the wheel *b* drives a pinion on the axle of the wheel *c*; the teeth of the wheel *c* are engaged with those of a pinion on the wheel *d*. The movement of the train is stopped, when the catch *e* falls under the tooth of the wheel *d*. The wheel *i*, which is engaged in the anchor of the escapement *g*, is fixed upon the axle of the wheel *c*, turns with the latter, and thus gives an oscillating motion to the anchor, which is imparted to the hammer *h* of the bell D. The bell is therefore acted upon by the hammer so long as the magnet A keeps the catch *e* from falling under the tooth of the wheel *d*.

159. Since the magnitude, loudness or pitch of the bell is independent of the force of the current, the telegraphic offices are provided with various bells for special purposes.

Sometimes a special wire is appropriated to the bell which is acted upon by a special current.

In other cases the regular current intended to work the telegraph is diverted to the bell apparatus by the commutator. In other cases again, the object is accomplished by the expedient explained in (134), which is known as the *short circuit*.

---

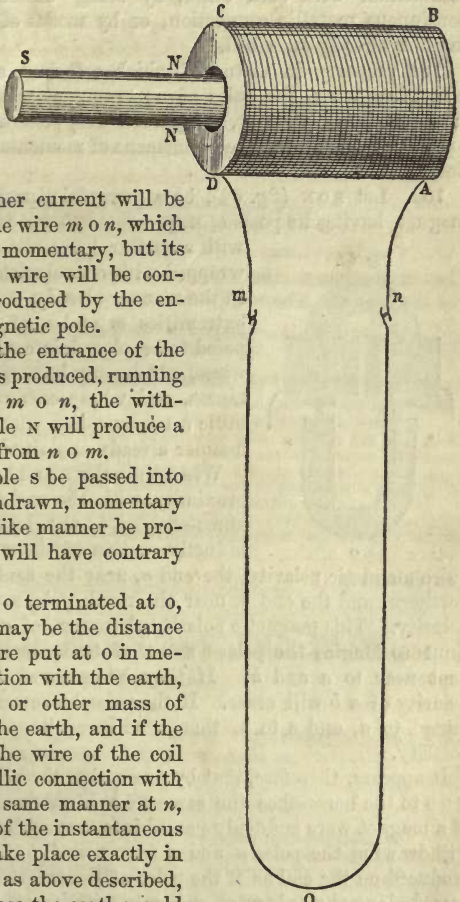
160. Having explained the form and construction of electro-magnets, we are prepared to show the manner in which an electric current may be produced by the mere action of magnets without any intervention of a voltaic battery.

The electricity thus produced has been called MAGNETO-ELECTRICITY.

161. Let a silk or cotton covered wire be coiled heliacally on a roller or bobbin having a hollow core of sufficient magnitude to allow a cylindrical bar to be passed into it. Let the covered wire be coiled constantly in the same direction, beginning from A B, (fig. 61), and terminating at C D. Let the extremities *m n* of this wire be joined to those of a wire *m* O *n* of any required length, stretched to any required distance. Now let the north pole N of a magnet S N be suddenly passed into the core of the

bobbin. An electric current will then be transmitted on the wire *m* o *n*, the presence of which may be rendered manifest by a galvanometer. This current, however, will be only momentary, being manifested only at the moment the pole of the magnet enters the core of the bobbin. It ceases immediately after that entrance.

Fig. 61.




Now if the magnetic bar after entering be as suddenly withdrawn, another current will be produced upon the wire *m* o *n*, which will also be only momentary, but its direction on the wire will be contrary to that produced by the entrance of the magnetic pole.

Thus if upon the entrance of the pole N a current is produced, running in the direction *m* o *n*, the withdrawal of the pole N will produce a current running from *n* o *m*.

If the south pole S be passed into the core and withdrawn, momentary currents will in like manner be produced, but they will have contrary directions.

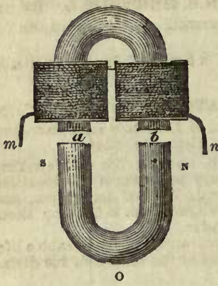
If the wire *m* o terminated at o, no matter what may be the distance of o from *m*, were put at o in metallic communication with the earth, or with a plate or other mass of metal buried in the earth, and if the extremity *n* of the wire of the coil were put in metallic connection with the earth in the same manner at *n*, the transmission of the instantaneous currents would take place exactly in the same manner as above described, because in that case the earth would play the part of a conductor between the end of the wire *m* o at o, and the end of the coil wire *n*.

But if the metallic continuity either of the wire *m* o *n*, in case it extended from *m* to *n*, or of *m* O if it were as described above in connection with the earth at O, were anywhere broken, no current would be produced by the entrance or withdrawal of the magnet. It is therefore essential to the production of these phenomena that the extremities *m* and *n* of the coil wire shall be in electric communication with each other, by being united either with a continuous metallic connection, or by means of the earth in the manner already described.

The property in virtue of which soft iron acquires magnetic properties, when the poles of a permanent magnet are brought into proximity with it, supplies a very convenient method of exhibiting the play of the phenomena of momentary currents above described.

162. Let S O N (fig. 62), be a powerful permanent horse-shoe magnet, having its poles S, N, presented to and in close proximity with a similar horse-shoe *a b* of soft iron, wrapped with convolutions of covered wire in the manner already described. Let the extremities *m* and *n* of the coil be supposed to be placed in connection with two wires, which may be extended to any distances, and whose extremities are in metallic communication with the earth in the manner already explained.

Fig. 62.




When the poles S and N are brought into proximity with the ends *a* and *b* of the horse-shoe *a b*, the latter will, by the inductive action of the magnet S O N, acquire magnetic polarity, the end *a*, near the south pole S, having northern, and the end *b*, near the north pole N, having southern polarity. This magnetic polarity, however, of *a b* will only continue so long as the poles S and N of the permanent magnet are kept near to *a* and *b*. If they be removed, that instant the polarity of *a b* will cease. If the poles be reversed, N being presented to *a*, and S to *b*, then *a* will acquire south, and *b* north polarity.

It appears, therefore, that by presenting the poles of the magnet N O S to the horse-shoe the same effect is produced as if the poles of a magnet were suddenly passed into the axis of the coil, and by withdrawing the poles N and S from *a* and *b*, the same effect is produced on the coil as if the poles of the magnet which had been passed along the axis were suddenly withdrawn.

London, *August*, 1854.

# WORKS

PUBLISHED BY

# WALTON AND MABERLY,

UPPER GOWER STREET, AND IVY LANE, PATERNOSTER ROW.

## RELIGIOUS BIOGRAPHY.

**FAR above Rubies.** A MEMOIR OF HELEN S. HERSCHELL. By her Daughter. Edited by the Rev. Ridley H. Herschell. Foolscap 8vo, 6*s.* 6*d.* cloth.

*** The Volume also contains the "Bystander," a Series of Papers originally contributed by Mrs. Herschell to a periodical work.

**A Memoir of the Rev. James Crabb,** LATE OF SOUTHAMPTON. THE "GIPSY ADVOCATE." By John Rudall, of Lincoln's Inn, Barrister-at-Law. One Vol., Crown 8vo. With a Portrait on Steel. 6*s.* cloth.

"James Crabb, however, was a remarkable man, and his life is a striking example of energy and perseverance; for without any advantages of education, connexion, fortune, or position, he acquired a certain kind of distinction, and accomplished greater things for philanthropy and religion than is done by thousands possessed of more than all he wanted."—*Spectator.*

"The Author has presented us with a faithful portraiture of Mr. Crabb's life, character, persevering labours, and never-tiring zeal in the service of his divine Master."—*Hampshire Independent.*

## EMBOSSED BOOKS FOR THE BLIND.

By Mr. Frere.

**OLD TESTAMENT.**

Genesis, 8*s.*—Exodus, 7*s.*
Joshua, 4*s.* 6*d.*—Judges, 4*s.* 6*d.*
Samuel I., 6*s.*—Samuel II., 5*s.* 6*d.*
Job, 5*s.*—Proverbs, 5*s.* 6*d.*
Psalms, Part I., 6*s.* 6*d.*
Psalms, Part II., 5*s.* 6*d.*
Isaiah, 7*s.* 6*d.*
Daniel, Esther, and Ruth, 5*s.* 6*d.*

**NEW TESTAMENT** (In 8 Vols.).

Matthew, 6*s.*
Mark, 5*s.* 6*d.*
Luke, 7*s.*
John, 5*s.* 6*d.*
Acts, 7*s.*
Romans to Corinthians, 6*s.*
Galatians to Philemon, 5*s.* 6*d.*
Hebrews to Revelations, 7*s.*

Morning Prayers, 2*s.*
Shepherd of Salisbury Plain, 2*s.*
Olney Hymns, 2*s.*

A Grammar, 1*s.*
Five Addresses to those who wish to go to Heaven, 1*s.* 6*d.*

Art of Teaching to Read by Elementary Sounds, 1*s.* 6*d.*

## JURISPRUDENCE.

**ELEMENTS of Jurisprudence.** By CHARLES JAMES FOSTER, M.A., LL.D., Professor of Jurisprudence in University College, London. Crown 8vo, 5*s.* cloth.

"Mr. Foster treats his subject in a masterly manner, and his volume may be read with profit both by students and men of the world."—*Athenæum.*

## LOGIC.

**THE Art of Reasoning;** A Popular Exposition of the Principles of Logic, Inductive and Deductive, with an Introductory Outline of the History of Logic, and an Appendix on Recent Logical Developments. By SAMUEL NEIL. Crown 8vo, 4*s.* 6*d.*

"This work is of undoubted merit. It displays a great thoughtfulness and research, and contains a vast amount of useful information on the subject of which it treats. The author seems to have thoroughly mastered his subject, and to the illustration of it has skilfully applied his extensive and varied knowledge."—*Glasgow Constitutional.*

**An Investigation of the Laws of Thought,** on which are founded the Mathematical Theories of Logic and Probabilities. By GEORGE BOOLE, Professor of Mathematics in Queen's College, Cork. One Vol. 8vo, 14*s.* cloth.

**Formal Logic; or, the Calculus of Inference necessary and** PROBABLE. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Cheap Issue, 8vo, 6*s.* 6*d.*

## HISTORY, ANTIQUITIES, &c.

**DICTIONARY of Greek and Roman Biography.** Edited by WILLIAM SMITH, LL.D., Editor of the Dictionaries of "Greek and Roman Antiquities," and of "Biography and Mythology." With very numerous Illustrations on Wood. Volume I. (1100 pages), 1*l.* 16*s.* cloth lettered.

The Work will be continued in Quarterly Parts, each 4*s.*, and will be completed in Two Volumes.

**Dictionary of Greek and Roman Biography and Mythology.** Edited by WILLIAM SMITH, LL.D., Classical Examiner in the University of London. Medium 8vo. Illustrated by numerous Engravings on Wood. Complete in Three Vols., 5*l.* 15*s.* 6*d.*

**Dictionary of Greek and Roman Antiquities.** By various Writers. Edited by Dr. WILLIAM SMITH. Second Edition. Revised throughout, with very numerous Additions and Alterations. One thick Volume, medium 8vo, with several hundred Engravings on Wood, 2*l.* 2*s.*

**A New Classical Dictionary of Ancient Biography, Mythology,** AND GEOGRAPHY. Edited by Dr. WILLIAM SMITH. New Edition. One Volume, 8vo, 15*s.* cloth.

This work comprises the same subjects as are contained in the well-known Dictionary of Lemprière, avoiding its errors, supplying its deficiencies, and exhibiting in a concise form the *results* of the labours of modern scholars. It will thus supply a want that has been long felt by most persons engaged in tuition.

**A Smaller Dictionary of Antiquities**; Selected and Abridged from the "Dictionary of Greek and Roman Antiquities." By WILLIAM SMITH, LL.D. New and Cheaper Edition. One small Volume, Two Hundred Woodcuts, 7*s.* 6*d.* cloth.

**A Smaller Classical Dictionary.** Abridged from the larger work. By Dr. WILLIAM SMITH. Cheaper Edition. Two Hundred Woodcuts, Crown 8vo, 7*s.* 6*d.* cloth.

**Niebuhr's History of Rome, from the Earliest Times to the** FALL OF THE WESTERN EMPIRE. Translated by BISHOP THIRLWALL, ARCHDEACON HARE, Dr. WILLIAM SMITH, and Dr. SCHMITZ. Fourth and Cheaper Edition. Three Vols., 8vo, 36*s.*

**Niebuhr's Lectures on Roman History.** Translated and Edited by LEONHARD SCHMITZ, Ph. D., Rector of the High School of Edinburgh. New and Cheaper Edition, in Three Vols. 8vo, 24*s.*

**Niebuhr's Lectures on Ancient History,** comprising the Asiatic Nations, the Egyptians, Greeks, Carthaginians, and Macedonians. Translated by Dr. L. SCHMITZ. Three Vols. 8vo, 1*l.* 11*s.* 6*d.*

In reference to Babylonia, Assyria, and Egypt, it is particularly interesting to notice how clearly the historian foresaw and anticipated all the great discoveries which have since been made in those countries. A thousand points in the history of ancient nations, which have hitherto been either overlooked or accepted without inquiry, are here treated with sound criticism and placed in their true light.

**Niebuhr's Lectures on Ancient Ethnography and Geography.** Comprising Greece and her Colonies, Italy, the Islands of the Mediterranean, Spain, Gaul, Britain, Northern Africa, and Phœnicia. Translated from the German by DR. LEONHARD SCHMITZ, F.R.S.E., Rector of the High School of Edinburgh, with additions and corrections from his own Notes. Two Vols., 8vo, 1*l.* 1*s.* cloth.

**A History of Rome; from the Earliest Times to the Death of** COMMODUS, A.D. 192. By Dr. L. SCHMITZ, Rector of the High School of Edinburgh, Editor of "Niebuhr's Lectures." New Edition. With 100 Illustrations on Wood. One thick Vol., 12mo, 7*s.* 6*d.* cloth.

**Questions on Schmitz's History of Rome.** By JOHN ROBSON, B.A. 12mo, 2*s.* cloth.

**A History of Greece.** With Supplementary Chapters on the Literature, Art, and Domestic Manners of the Greeks. By William Smith, LL.D., Editor of the Dictionaries of "Greek and Roman Antiquities," "Biography," &c. Woodcuts and Maps. Post 8vo, 7*s.* 6*d.* cloth.

"A good plan capitally executed, is the characteristic of Dr. Smith's introductory History of Greece."—*Spectator.*

**Four Lectures on the Contrasts of Ancient and Modern** HISTORY. By F. W. NEWMAN, Professor of Latin in University College, London. Foolscap 8vo, 3*s.* cloth.

**The Book of Almanacs.** With Index, by which the Almanac belonging to any year preceding A.D. 2000 can be found; with means of finding New and Full Moons from B.C. 2000 to A.D. 2000. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Demy 8vo, oblong, 5*s.* cloth.

"This is quite a novelty in chronological literature. It is an *universal almanac*—universal, that is, as respects time, past, present, and future. The main object of it is, as the compiler states, to supply the place of an old almanac, which is never at hand when wanted; of the older almanac, which never was at hand; and of the universal almanac in every shape! A more useful chronological handbook could scarcely be conceived. It will save an immensity of calculation, and is in many other respects invaluable as a chronological guide and instructor."—*Oxford Herald.*

**A Numismatic Manual;** or, Guide to the Collection and Study of Greek, Roman, and English Coins. Illustrated by Engravings of many hundred types, by means of which even imperfect and obliterated pieces may be easily deciphered. By J. Y. AKERMAN, F.S.A. 8vo, 21*s.* cloth.

## POETRY.

**DISCOVERY.** A POEM. By EDWARD ALDAM LEATHAM, M.A. Foolscap 8vo, 2*s.* 6*d.* cloth.

"His execution is finished and of a good school."—*Spectator.*

"Mr. Leatham's style is vigorous, his lines are musical, and his versification is correct. * * His peroration is truly eloquent."—*Britannia.*

**Love in the Moon;** A POEM. With Remarks on that Luminary. By PATRICK SCOTT, Author of "Lelio." Foolscap 4to, 5*s.* 6*d.* cloth gilt.

**Poetical Works of John Keats.** Royal 8vo, sewed, 2*s.*

**A Collection of Poetry for the Practice of Elocution.** Made for the use of the Ladies' College, Bedford Square. By Professor F. W. NEWMAN. Foolscap 8vo, 2*s.* 6*d.*

**The Georgics of Virgil.** Translated into Verse by the Rev. W. H. BATHURST, M.A., Rector of Barwick-in-Elmet. Foolscap 8vo, 4*s.* 6*d.* cloth.

## MISCELLANEOUS.

**BUSINESS as it is and as it might be.** By JOSEPH LYNDALL. Crown 8vo, 1*s.* sewed, 1*s.* 6*d.* cloth.

*** This Work obtained the Prize of Fifty Guineas offered by the Young Men's Christian Association for the best Essay on "The Evils of the Present System of Business, and the Difficulties they Present to the Attainment and Development of Personal Piety, with Suggestions for their Removal."

**Suggestions on Female Education.** Two Introductory Lectures on English Literature and Moral Philosophy, delivered in the Ladies' College, Bedford Square, London. By A. J. SCOTT, A.M., Principal of Owen's College, Manchester, late Professor of the English Language and Literature in University College, London. Foolscap 8vo, 1*s.* 6*d.*

**Guesses at Truth.** By TWO BROTHERS. New Edition. Foolscap 8vo. First Series, 6*s.*; Second Series, 7*s.*

**Mr. Frere's Works on Prophecy.**

BRIEF INTERPRETATION OF THE APOCALYPSE. 8vo, 3*s.* 6*d.* cloth.

GENERAL STRUCTURE OF THE APOCALYPSE, chiefly relating to the Individual Antichrist of the Last Days. 8vo, 2*s.*

THREE LETTERS ON THE PROPHECIES. 8vo, 2*s.*

EIGHT LETTERS ON THE PROPHECIES; viz. on the Seventh Vial; the Civil and Ecclesiastical Periods; and on the Type of Jericho. 8vo, 2*s.* 6*d.*

GREAT CONTINENTAL REVOLUTION, marking the expiration of the "Times of the Gentiles." 8vo, 2*s.* 6*d.*

## STEAM NAVIGATION AND RAILWAYS.

**THE Steam Engine, Steam Navigation, Roads, and Railways,** EXPLAINED AND ILLUSTRATED. A New and Cheaper Edition, revised and completed to the present time. By DIONYSIUS LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, London. One Vol., 12mo, Illustrated with Wood Engravings, 8*s.* 6*d.* cloth.

**Railway Economy; or, the New Art of Transport.** Its Management, Prospects, and Relations, Commercial, Financial, and Social; with an Exposition of the Practical Results of the Railways in operation in the United Kingdom, on the Continent, and in America. By DIONYSIUS LARDNER, D.C.L. One Vol., large 12mo.

**Sketch of the Origin and Progress of Steam Navigation.** By BENNET WOODCROFT, late Professor of Machinery in University College, London. With 17 Lithographic Plates, Fcap. 4to, 12*s.* cloth.

**The Pneumatics of Hero of Alexandria;** from the Original Greek. Translated for and Edited by BENNET WOODCROFT, late Professor of Machinery in University College, London. Fcap. 4to, 12*s.* 6*d.* cloth.

## NATURAL PHILOSOPHY AND ASTRONOMY.

**FAMILIAR Letters on the Physics of the Earth.** By H. BUFF, Professor of Physics in the University of Giessen. Edited by Dr. A. W. HOFMANN, Professor in the Royal College of Chemistry, London. Fcap. 8vo, 5*s.*

Introduction.—Gravity and its Effects.—Tides.—Heat within the Earth.—Warm Springs.—Hot Springs and Jets of Steam.—Jets of Gas and Mud Volcanoes.—Volcanoes and Earthquakes.—Temperature of the Outermost Crust of the Earth.—Temperature of the Lowest Layer of the Atmosphere.—Lines of equal Heat.—Temperature of the Upper Layers of the Atmosphere.—The Snow Limits.—Glaciers.—Temperature of the Waters, and their Influence on Climate.—Currents of the Sea.—Winds.—Moisture of the Air and Atmospheric Precipitation.—Electricity of the Air, Lightning, and Thunder.

**An Elementary Treatise on Mechanics,** for the Use of Junior University Students. By RICHARD POTTER, A.M., Professor of Natural Philosophy in University College, London. Second Edition, 8vo, with numerous Diagrams, 8*s.* 6*d.* cloth.

**An Elementary Treatise on Optics,** PART I. By RICHARD POTTER, A.M. Second Edition, 8vo, corrected, with numerous Diagrams, 9*s.* 6*d.* cloth.

**An Elementary Treatise on Optics,** PART II., Containing the Higher Propositions. By RICHARD POTTER, A.M. 8vo, with numerous Diagrams, 12*s.* 6*d.*

This volume contains the discussions of direct and oblique pencils to the higher approximations according to previously known methods. Also new discussions of the *aberrations of oblique pencils* and the forms of the images produced; together with the application to the theory of Optical Instruments. Many other new investigations will be found in the volume.

**Twelve Planispheres,** forming a Guide to the Stars for every Night in the Year, with an Introduction. 8vo, 6*s.* 6*d.* cloth.

**Ecliptical Charts, Hours, 1, 2, 3, 4, 5, 7, 9, 10, 11, and 13,** taken at the Observatory, Regent's Park, under the direction of GEORGE BISHOP, Esq., F.R.S., &c. 2*s.* 6*d.* each.

**Astronomical Observations,** taken at the Observatory, Regent's Park, during the Years 1839—1851, under the direction of GEORGE BISHOP, Esq. F.R.S., &c. 4to, 12*s.* 6*d.*

# DR. LARDNER'S

# MUSEUM OF SCIENCE AND ART.

A Miscellany of

INSTRUCTIVE AND AMUSING TRACTS ON THE PHYSICAL SCIENCES, AND ON THEIR APPLICATION TO THE USES OF LIFE.

## ILLUSTRATED BY ENGRAVINGS ON WOOD.

"'Dr. Lardner's Museum,' one of the few works of the kind which can be recommended as at once popular and accurate."—*Sir David Brewster.*

"This series, besides affording popular but sound instruction on scientific subjects, with which the humblest man in the country ought to be acquainted, also undertakes that teaching of 'Common Things' which Lord Ashburton and every well-wisher of his kind are anxious to promote. Many thousand copies of this serviceable publication have been printed, in the belief and hope that the desire for instruction and improvement widely prevails; and we have no fear that such enlightened faith will meet with disappointment."—*The Times, Feb.* 9, 1854.

"This serial, which will form quarterly eighteenpenny volumes, is, we are disposed to think, the best literary investment of a penny a week now extant."—*Examiner.*

"A cheap and interesting publication, alike informing and attractive. The papers combine subjects of importance with great scientific knowledge, considerable inductive powers, and a popular style of treatment."—*Spectator.*

## CONTENTS OF

### VOL. I., *price* 1*s.* 6*d.*, *in handsome boards.*

PART I., price 5*d.*

1. The Planets; Are they Inhabited Globes?
2. Weather Prognostics.
3. The Planets. Chap. II.
4. Popular Fallacies in Questions of Physical Science.

PART II., price 5*d.*

5. Latitudes and Longitudes.
6. The Planets. Chap. III.
7. Lunar Influences.
8. Meteoric Stones and Shooting Stars. Chap. I.

PART III., price 6*d.*

9. Railway Accidents. Chap. I.
10. The Planets. Chap. IV.
11. Meteoric Stones and Shooting Stars. Chap. II.
12. Railway Accidents. Chap. II.
13. Light.

### VOL. II., *price* 1*s.* 6*d.*, *in handsome boards.*

PART IV., price 5*d.*

14. Common Things.—Air.
15. Locomotion in the United States. Chap. I.
16. Cometary Influences. Chap. I.
17. Locomotion in the United States. Chap. II.

PART V., price 5*d.*

18. Common Things.—Water.
19. The Potter's Art. Chap. I.
20. Locomotion in the United States. Chap. III.
21. The Potter's Art. Chap. II.

PART VI., price 6*d.*

22. Common Things.—Fire.
23. The Potter's Art. Chap. III.
24. Cometary Influences. Chap. II.
25. The Potter's Art. Chap. IV.
26. The Potter's Art. Chap. V.

### CONTENTS OF VOL. III., *price* 1*s.* 6*d.*, *in handsome boards.*

PART VII., price 5*d.*

27. Locomotion and Transport, their Influence and Progress. Chap. I.
28. The Moon.
29. Common Things.—The Earth.
30. Locomotion and Transport, their Influence and Progress. Chap. II.

PART VIII., price 5*d.*

31. The Electric Telegraph. Chap. I.
32. Terrestrial Heat. Chap. I.
33. The Electric Telegraph. Chap. II.
34. The Sun.

## DR. LARDNER'S MUSEUM *(Continued)* :—

VOL. III., Part IX., price *6d.*

35. The Electric Telegraph. Chap. III.
36. Terrestrial Heat. Chap. II.
37. The Electric Telegraph. Chap. IV.
38. The Electric Telegraph. Chap. V.
39. The Electric Telegraph. Chap. VI.

*** *This work is continued in Weekly Numbers at* 1*d.*, *in Monthly Parts at* 5*d.*, *and Quarterly Volumes at* 1*s.* 6*d.*, *in Ornamental Boards.*

**First Book of Natural Philosophy**; or, an Introduction to the Study of Statics, Dynamics, Hydrostatics, and Optics, with numerous examples. By Samuel Newth, M.A., Fellow of University College, London. 12mo, 3*s.* 6*d.*

**Handbook of Natural Philosophy and Astronomy.** By Dionysius Lardner, formerly Professor of Natural Philosophy and Astronomy in University College, London. Three Vols., large 12mo, with very numerous Illustrations on Wood.

**FIRST COURSE,** One Vol., 12*s.* 6*d.* cloth, contains :—Mechanics; Hydrostatics; Hydraulics; Pneumatics; Sound; Optics.

"We have much pleasure in recommending Dr. Lardner's 'Handbook of Natural Philosophy;' it is one of the best popular scientific works that has yet appeared."—*English Journal of Education.*

"Our examination of the work leads us to speak most favourably of it as a handbook for students; it will be a useful addition to the library of every medical student, as well as a serviceable guide to all who are about to commence the study of physics."—*Medical Gazette.*

**SECOND COURSE,** One Vol., 8*s.* 6*d.*, contains:—Heat; Common Electricity; Magnetism; Voltaic Electricity.

**THIRD COURSE,** One Vol., 16*s.* 6*d.*, contains: — Astronomy and Meteorology. With 37 Plates and 200 Woodcuts.

*** *Any volume may be purchased separately.*

# CURRENCY.

**A CATECHISM of the Currency.** By John Taylor. Third Edition, 12mo, 2*s.*

**A Catechism of the Foreign Exchanges.** By John Taylor, Second Edition, 12mo, 2*s.*

**A View of the Money System of England.** By James Taylor. 8vo, 3*s.* sewed.

# MATHEMATICS, &c.

**ELEMENTS of Arithmetic.** By Augustus De Morgan, Professor of Mathematics in University College, London. Fifth Edition, with Eleven Appendixes, Royal 12mo, 5*s.* cloth.

**De Morgan's Elements of Algebra.** Preliminary to the Differential Calculus. Second Edition. Royal 12mo, 9*s.* cloth.

**De Morgan's Trigonometry and Double Algebra.** Royal 12mo, 7*s.* 6*d.* cloth.

**Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots,** AND RECIPROCALS, up to 10,000. Stereotype Edition, examined and corrected. Under the superintendence of the Society for the Diffusion of Useful Knowledge. Royal 12mo, cloth, 8*s.*

**Arithmetical Books and Authors.** From the Invention of Printing to the present time; being Brief Notices of a large Number of Works drawn up from actual inspection. By AUGUSTUS DE MORGAN, Professor of Mathematics in University College, London. Cheap issue. Royal 12mo, 2*s.* 6*d.* cloth.

"A great number of persons are employed in teaching Arithmetic in the United Kingdom. In publishing this work, I have the hope of placing before many of them more materials for the prevention of inaccurate knowledge of the literature of their science than they have hitherto been able to command, without both expense and research."—*Preface.*

**A Course of Arithmetic as Taught in the Pestalozzian School,** WORKSOP. By J. L. ELLENBERGER. 12mo. 5*s.* cloth.

**The First Book of Euclid Explained to Beginners.** By C. P. MASON, B.A., Fellow of University College, and Principal of Denmark Hill Grammar School. Fcap. 8vo. 1*s.* 9*d.* cloth.

**Reiner's Lessons on Form; or, an Introduction to Geometry,** as given in a Pestalozzian School, Cheam, Surrey. 12mo, with numerous Diagrams, 3*s.* 6*d.* cloth.

**A First Book on Plane Trigonometry.** Geometrical Trigonometry, and its applications to Surveying, with numerous Examples. For the use of Schools. By G. W. HEMMING, M.A., Fellow of St. John's College, Cambridge, and Author of a Treatise on the "Differential and Integral Calculus." With Diagrams, 12mo, cloth limp, 1*s.* 6*d.*

**Ritchie's Principles of Geometry,** familiarly Illustrated, and applied to a variety of useful purposes. Designed for the Instruction of Young Persons. Second Edition, revised and enlarged, 12mo, with 150 Woodcuts, cloth limp, 1*s.* 6*d.*

**Tables of Logarithms, Common and Trigonometrical, to Five** PLACES. Under the Superintendence of the Society for the Diffusion of Useful Knowledge. Fcap. 8vo, cloth limp, 1*s.* 6*d.*

**Lessons on Number,** as given at the Pestalozzian School, Cheam, Surrey. By CHARLES REINER. The Master's Manual. New Edition. 12mo, cloth, 5*s.* The Scholar's Praxis. 12mo, 2*s.* bound.

## GREEK.

**THE Anabasis of Xenophon.** Expressly for Schools. With Notes, a Geographical and Biographical Index, and a Map. By J. T. V. HARDY, B.A., Principal of Huddersfield College; and ERNEST ADAMS, Classical Master in University College School. 12mo, 4*s.* 6*d.* cloth.

**Lexicon to Aeschylus.** Containing a Critical Explanation of the more Difficult Passages in the Seven Tragedies. By the Rev. W. LINWOOD, A.M., M.R.A.S. Second Edition. Revised. 8vo, 12*s.* cloth.

**New Greek Delectus;** Being Sentences for Translation from Greek into English, and English into Greek; arranged in a Systematic Progression. By Dr. RAPHAEL KUHNER. Translated and Edited from the German, by Dr. ALEXANDER ALLEN. Third Edition, revised. 12mo, 4*s.* cloth.

**Four Gospels in Greek.** For the use of Schools. Fcap. 8vo. cloth limp, 1s. 6d. This part of the Greek Testament is printed separately for the use of Students beginning to learn Greek, the Evangelists being more generally read than the rest of the Testament.

**London Greek Grammar.** Designed to exhibit, in small compass, the Elements of the Greek Language. Edited by a GRADUATE of the University of Oxford. Fifth Edition. 12mo, cloth limp, 1s. 6d.

**Greek Testament.** GRIESBACH's TEXT, with the various readings of MILL and SCHOLZ. Second Edition, revised. Fcap. 8vo, cloth, 6s. 6d.; morocco, 12s. 6d.

**Plato.** The Apology of SOCRATES, CRITO, and part of the PHAEDO, with English Notes, a Life of Socrates, &c. Edited by Dr. W. SMITH. Second Edition. 12mo, cloth, 5s.

**Robson's Constructive Greek Exercises.** 12mo, cloth, 7s. 6d.

*** This Work, which was originally intended to be a new edition of "Allen's Constructive Greek Exercises," will take the place of that book. The general principles of both are identical.

**Introduction to the Art of Composing Greek Iambics,** in Imitation of the Greek Tragedians. Designed for the use of Schools. By the Rev. CHARLES TAYLER. 12mo, 2s. 6d.

**What is the Power of the Greek Article;** and how may it be expressed in the English Version of the New Testament? By JOHN TAYLOR. 8vo, 2s. 6d.

## LATIN.

**NEW Latin Delectus;** being Sentences for Translation from Latin into English, and English into Latin; arranged in a Systematic Progression, on the plan of the Greek Delectus. By Dr. ALEXANDER ALLEN. Third Edition, 12mo, 4s. cloth.

**Constructive Latin Exercises,** for teaching the Elements of the Language on a System of Analysis and Synthesis; with Latin Reading Lessons, and copious Vocabularies. By JOHN ROBSON, B.A., late Assistant Master in University College School. Second Edition, thoroughly revised. 12mo, 6s. 6d. cloth.

**London Latin Grammar;** including the Eton Syntax and Prosody in English, accompanied with Notes. Edited by a GRADUATE of the University of Oxford. Fifteenth Edition. 12mo, 1s. 6d. cloth limp.

**First Latin Reading Lessons;** with complete Vocabularies. Intended as an Introduction to Cæsar. By JOHN ROBSON, B.A., Assistant Master in University College School. 12mo, 2s. 6d. cloth.

**The Principal Roots of the Latin Language,** simplified by a display of their Incorporation into the English Tongue; with copious Notes. By HENRY HALL. Fifth Edition. 12mo, 1s. 6d. cloth limp.

**The Germania of Tacitus.** With Ethnological Dissertations and Notes. By Dr. R. G. LATHAM. Author of the "English Language," &c. With a Map. Demy 8vo, 12s. 6d.

**Tacitus, Germania, Agricola,** and First Book of the Annals. With Notes Translated into English from RUPERTI, PASSOW, and WALCH, and BOTTIGER'S Remarks on the style of TACITUS. Second Edition. Edited by Dr. W. SMITH. 12mo, 5s. cloth.

**Caesar for Beginners.** Latin and English; with the Original Text at the end. 12mo, 3 . 6d. cloth.

**Mythology for Versification;** or, a Brief Sketch of the Fables of the Ancients, prepared to be rendered into Latin verse. By the late Rev. F. HODGSON, M.A. (Provost of Eton). New Edition. 12mo, 3s. bound. KEY to Ditto. 8vo, 7s.

**Select Portions of Sacred History,** conveyed in sense for Latin Verses. By the late Rev. F. HODGSON, M.A. (Provost of Eton). Third Edition. 12mo, 3s. 6d. cloth. KEY to Ditto. Royal 8vo, 10s. 6d. cloth.

**Sacred Lyrics;** or, Extracts from the Prophetical and other Scriptures of the Old Testament; adapted to Latin Versification in the principal Metres of HORACE. By the late Rev. F. HODGSON, M.A. (Provost of Eton). 12mo, 6s. 6d. cloth. KEY to Ditto. 8vo, 12s. cloth.

**Latin Authors.** Selected for the use of Schools; containing portions of Phædrus, Ovid's Metamorphoses, Virgil's Æneid, Cæsar and Tacitus. 12mo, 1s. 6d. cloth,

## HEBREW.

**GRAMMAR of the Hebrew Language.** By HYMAN HURWITZ, late Professor of Hebrew in University College, London. Fourth Edition, revised and enlarged. 8vo, 13s. cloth. Or in Two Parts, sold separately:—ELEMENTS, 4s. 6d. cloth; ETYMOLOGY and SYNTAX, 9s. cloth.

**Book of Genesis in English Hebrew;** accompanied by an Interlinear Translation, substantially the same as the authorised English version; Philological Notes, and a Grammatical Introduction. By W. GREENFIELD, M.R.A.S. Fourth Edition. Cheap Issue. 8vo, 4s. 6d. cloth. With the original Text in Hebrew characters at the end. 8vo, 6s. 6d. cloth.

## MAPS.

**TEACHING Maps:**—I. RIVERS AND MOUNTAINS, of England, Wales, and Part of Scotland. 6d. II.—TOWNS of Ditto. 6d.

**Projections.** Three Maps. MERCATOR. EUROPE. BRITISH ISLES. Stitched in a Cover, 1s. Single Maps, 4d. each.

**Projections;** with Outline of Country. Three Maps stitched in a Cover, 1s. Single Maps, 4d. each.

## ENGLISH.

**THE English Language.** By DR. R. G. LATHAM, F.R.S., late Fellow of King's College, Cambridge. Fourth Edition, greatly enlarged. 8vo. *In the Press.*

**An English Grammar for the Use of Schools.** By DR. R. G. LATHAM, F.R.S., late Fellow of King's College, Cambridge. Sixth Edition. 12mo, 4s. 6d. cloth.

**Elements of English Grammar, for the Use of Ladies' Schools.** By Dr. R. G. LATHAM, F.R.S. Fcap. 8vo, 1s. 6d. cloth.

**Elements of English Grammar, for Commercial Schools.** By Dr. R. G. LATHAM, F.R.S. Fcap. 8vo, 1s. 6d. cloth.

**A Handbook of the English Language.** By Dr. R. G. LATHAM, F.R.S. 12mo, 8s. 6d. cloth.
The object of the "Handbook" is to present to students for examination, in a more condensed form, the chief facts and reasonings of "The English Language." Less elaborate than that work, it is less elementary than the "English Grammar." Like all the other works by the same author, it gives great prominence to the ethnological relations of our tongue; and insists upon historical investigation, and the application of the general principles of comparative philology, as the true means of exhibiting its real growth and structure, in opposition to the more usual method of treating it as a mass of irregularities. It has the further object of supplying a knowledge of those laws of speech and principles of grammar which apply to language generally.

**History and Etymology of English Grammar, for the Use of** CLASSICAL SCHOOLS. By Dr. R. G. LATHAM, F.R.S. Fcap. 8vo, 1s. 6d. cloth.

**First Outlines of Logic,** applied to Grammar and Etymology. By Dr. R. G. LATHAM. 12mo, 1s. 6d. cloth.

**New English Spelling Book.** By the Rev. GORHAM D. ABBOTT. Second Edition, with Reading Lessons. 12mo, sewed, 6d.

**First English Reader.** By the Rev. G. D. ABBOTT. 12mo, with Illustrations. 1s. cloth limp.

**Second English Reader.** By the Rev. G. D. ABBOTT. 12mo, 1s. 6d. cloth limp.

## FRENCH.

**MERLET'S French Grammar.** By P. F. MERLET, Professor of French in University College, London. New Edition, 12mo, 5s. 6d. bound. Or, sold in two Parts: PRONUNCIATION and ACCIDENCE, 3s. 6d.; SYNTAX, 3s. 6d. (KEY, New Edition, 3s. 6d.)

**Merlet's Traducteur;** Or, HISTORICAL, DRAMATIC, and MISCELLANEOUS SELECTIONS from the best FRENCH WRITERS; accompanied by Explanatory Notes; a selection of Idioms, &c. New Edition. 12mo, 5s. 6d. bound.

**Merlet's Dictionary of the Difficulties of the French Language;** containing Explanations of every Grammatical Difficulty: Synonymes explained in a concise manner; Versification; Etymological Vocabulary; Free Exercises, with Notes; Mercantile Expressions, Phrases, and Letters; Elements of French Composition. A new and enlarged Edition. 12mo, 6s. 6d. bound.

**Merlet's French Synonymes;** explained in Alphabetical Order, with Copious Examples. (From the "DICTIONARY OF DIFFICULTIES.") 12mo, 2s. 6d. cloth.

**Stories from French Writers.** Interlinear (from Merlet's "Traducteur"). 12mo, 2s.

## GERMAN.

**The Adventures of Ulysses:** a German Reading Book; with a short Grammar and a Vocabulary. By PAUL HIRSCH. Twenty-four Woodcuts. 12mo, 6s. cloth,

*Separately,*

**A Short Grammar of the German Language.** 12mo, cloth, 2s.

## ITALIAN.

**First Italian Course;** Being a Practical and Easy Method of Learning the Elements of the Italian Language. By W. BROWNING SMITH, M.A., Second Classical Master of the City of London School. Royal 18mo, cloth, 3s. 6d.

**Panizzi's Italian Grammar.** 12mo, cloth limp, 1s. 6d.

# INTERLINEAR TRANSLATIONS.

*Cheap Issue, at* 1*s.* 6*d. per volume.*

**LOCKE'S System of Classical Instruction,** restoring the Method of Teaching formerly practised in all Public Schools. The Series consists of the following Interlinear Translations with the Original Text, in which the quantity of the doubtful Vowels is denoted; critical and explanatory Notes, &c.

*** By means of these Works, that excellent system of Tuition is effectually restored which was established by Dean Colet, Erasmus, and Lily, at the foundation of St Paul's School, and was then enjoined by authority of the State, to be adopted in all other Public Seminaries of learning throughout the kingdom. Each Volume, 1*s.* 6*d.*

LATIN.

1. Phædrus's Fables of Æsop.
2. Ovid's Metamorphoses. Book I.
3. Virgil's Æneid. Book I.
4. Parsing Lessons to Virgil.
5. Cæsar's Invasion of Britain.

GREEK.

1. Lucian's Dialogues. Selections.
2. The Odes of Anacreon.
3. Homer's Iliad. Book I.
4. Parsing Lessons to Homer.
5. Xenophon's Memorabilia. Part I.
6. Herodotus's Histories. Selections.

FRENCH.—Sismondi; the Battles of Cressy and Poictiers.

GERMAN.—Stories from German Writers.

*** A Second Edition of the Essay, explanatory of the System, with an Outline of the Method of Study, is published. 12mo, sewed, price 6*d.*

# ANIMAL MAGNETISM.

**BARON Von Reichenbach's Researches on Magnetism, Elec-** TRICITY, HEAT, LIGHT, CRYSTALLISATION, AND CHEMICAL ATTRACTION, IN THEIR RELATION TO THE VITAL FORCE. Translated and Edited (at the express desire of the Author) by Dr. Gregory, of the University of Edinburgh. Cheap Issue. One Volume, 8vo, 6*s.* 6*d.*, cloth.

"The merits of this remarkable volume are great. The painstaking, conscientious, cautious, ingenious,—we had almost said the religious, and certainly the self-possessed enthusiasm with which the experimental clue is followed from turn to turn of the labyrinth, is surpassed by nothing of the same sort in the whole range of contemporary science."—*North British Review.*

# ANATOMY, MEDICINE, &c.

**DR. Quain's Anatomy.** Edited by Dr. Sharpey and Mr. Quain, Professors of Anatomy and Physiology in University College, London. Fifth Edition. Complete in Two Volumes, 8vo. Illustrated by four hundred Engravings on Wood. Price 2*l.*

**Demonstrations of Anatomy.** A Guide to the Dissection of the Human Body. By George Viner Ellis, Professor of Anatomy in University College, London. Third Edition. Small 8vo. 12*s.* 6*d.* cloth.

**Lectures on the Principles and Practice of Midwifery.** By Edward Wm. Murphy, A.M., M.D., Professor of Midwifery in University College, London. One Volume, 8vo, many Illustrations, 16*s.*

"The work will take rank among the best treatises on the obstetric art. By this work, Dr. Murphy has placed his reputation and his fame on a solid and durable foundation."—*Dublin Medical Press.*

**A Handbook of Physiology.** By WILLIAM SENHOUSE KIRKES, M.D., Demonstrator of Morbid Anatomy at St. Bartholomew's Hospital. Assisted by JAMES PAGET, Lecturer on General Anatomy and Physiology at St. Bartholomew's Hospital. Second Edition. One Volume 12mo, with Illustrations. 12*s*. 6*d*.

**Physical Diagnosis of the Diseases of the Abdomen.** By EDWARD BALLARD, M.D., Late Medical Tutor in University College, London. Large 12mo, 7*s*. 6*d*. cloth.

"The profession is much indebted to Dr. Ballard for this unpretending little volume, which, we feel certain, if carefully studied, will accomplish its object of removing many of the difficulties at present surrounding the diagnosis of abdominal diseases."—*Lancet*.

**A Practical Treatise on Diseases of the Heart and Lungs,** their Symptoms and Treatment, and the Principles of Physical Diagnosis. By W. H. WALSHE, M.D., Professor of the Principles and Practice of Medicine and Clinical Medicine in University College, London; Physician to University College Hospital, and Consulting Physician to the Hospital for Consumption and Diseases of the Chest. A new and considerably enlarged edition. One Volume, 12*s*. 6*d*. cloth.

"This work is what its name indicates it to be—eminently practical. That it will add largely to the already great reputation of its author, no question can be entertained. It is far in advance of any other Treatise on Diseases of the Chest, either in this or any other country. Every page—we were about to say every line—contains a fact, often new, and *always resting on the Author's own observations*. Cases are quoted to prove every new statement, and to support every argument adduced in opposition to others. To the practitioner, the clinical teacher, and to the student, this work will prove alike invaluable."—*Medical Times*.

**The Nature and Treatment of Cancer.** By W. H. WALSHE, M.D., Professor of Medicine in University College, Physician to University College Hospital, and Consulting Physician to the Hospital for Consumption and Diseases of the Chest. One Volume, 8vo, with Illustrations. Cheap Issue, 6*s*. 6*d*.

**The Diseases of the Rectum.** By RICHARD QUAIN, F.R.S., Professor of Clinical Surgery in University College, and Surgeon to University College Hospital. With Lithographic Plates. Post 8vo. 7*s*. 6*d*. cloth.

"This Treatise is eminently of a practical character, and contains much original and valuable matter. It is not indeed a literary compilation, but rather an exposition of the author's opinions and practice in those diseases."—*Association Journal*.

**The Science and Art of Surgery.** Being a Treatise on Surgical Injuries, Diseases, and Operations. By JOHN ERICHSEN, Professor of Surgery in University College, and Surgeon to University College Hospital. 250 Wood Engravings. 8vo. 1*l*. 5*s*.

"The aim of Mr. Erichsen appears to be, to improve upon the plan of Samuel Cooper; and by connecting in one volume the science and art of Surgery, to supply the student with a text-book and the practitioner with a work of reference, in which scientific principles and practical details are alike included.

"It must raise the character of the author, and reflect great credit upon the College in which he is Professor, and we can cordially recommend it as a work of reference, both to students and practitioners."—*Medical Times*.

**The Microscopic Anatomy of the Human Body in Health** AND DISEASE. Illustrated with numerous Drawings in Colour. By ARTHUR HILL HASSALL, M.B., Fellow of the Linnæan Society, Member of the Royal College of Surgeons, &c. &c. Two Vols., 8vo, 2*l*. 5*s*.

**Hassall's History of the British Freshwater Algæ,** including Descriptions of the Desmideæ and Diatomaceæ. With upwards of 100 Plates, illustrating the various species. Two Vols. 8vo, 2*l*. 5*s*.

**Morton's Surgical Anatomy of the Principal Regions.** Completed by Mr. CADGE, late Assistant Surgeon, University College Hospital. Twenty-five Lithographic Illustrations Coloured, and Twenty-five Woodcuts. Royal 8vo, 21*s.* cloth lettered. It may also be had as under—Perinæum, 5*s.*; Groin, Femoral, and Popliteal Regions, 7*s.* 6*d.*; Inguinal Hernia, Testis and its Coverings, 7*s.* 6*d.*; Head and Neck, the Axilla, and the Bend of the Elbow, 7*s.* 6*d.*

"The work thus completed constitutes a useful guide to the student, and remembrancer to the practitioner. We can speak very favourably of the general execution of the work. The coloured lithographs are, for the most part, well drawn, and faithfully represent the broad features of the several parts. The woodcuts are well engraved, and very clearly exhibit the points which they are intended to illustrate. We think that Mr. Cadge's contributions in no degree fall short of the original work; and we trust that the volume in its complete form will find a cordial reception from the profession.—*Medical Gazette.*

**A Series of Anatomical Plates in Lithography.** Edited by JONES QUAIN, M.D., and ERASMUS WILSON, F.R.S.

| | | Plain. | | | Coloured. | | |
|---|---|---|---|---|---|---|---|
| | | £ | *s.* | *d.* | £ | *s.* | *d.* |
| Muscles. | 51 Plates, bound | 1 | 18 | 0 | 3 | 12 | 0 |
| Vessels. | 50 Plates „ | 1 | 18 | 0 | 3 | 3 | 0 |
| Nerves. | 38 Plates „ | 1 | 10 | 0 | 2 | 16 | 0 |
| Viscera. | 32 Plates „ | 1 | 5 | 0 | 2 | 8 | 0 |
| Bones and Ligaments, 30 Plates | | 1 | 5 | 0 | 1 | 11 | 6 |

The work complete in 2 vols. royal folio, half-bound, morocco, gilt tops, price 8*l.* 8*s.* plain; 14*l.* coloured.

*** Proposals for publishing a remarkably cheap edition of this work have just been issued, and may be had of the Publishers.

**On Gravel, Calculus, and Gout;** chiefly an Application of Professor Liebig's Physiology to the Prevention and Cure of those Diseases. By H. BENCE JONES, M.D., F.R.S., Physician to St. George's Hospital. 8vo, cloth, price 6*s.*

## CHEMISTRY, &c.

**FAMILIAR Letters on Chemistry.** In its relations to Physiology, Dietetics, Agriculture, Commerce, and Political Economy. By JUSTUS VON LIEBIG. A New and Cheap Edition, revised throughout, with many additional Letters. Complete in one Volume, Foolscap 8vo, price 6*s.* cloth.

**Annual Report of the Progress of Chemistry,** and the Allied Sciences, Physics, Mineralogy, and Geology; including the Applications of Chemistry to Pharmacy, the Arts, and Manufactures. By PROFESSORS LIEBIG and KOPP, with the co-operation of Professors Buff, Dieffenbach, Ettling, Knapp, Will, and Zamminer. Edited by DR. HOFMANN and DR. BENCE JONES. Vols. 1, 2, and 3, for 1847, 1848, and 1849, 2*l.* Vol. 4 (1850), 1*l.* 1*s.*

**Practical Pharmacy.** The Arrangements, Apparatus, and Manipulations of the Pharmaceutical Shop and Laboratory. By FRANCIS MOHR, Ph. D., of Coblentz; and THEOPHILUS REDWOOD, Professor of Chemistry and Pharmacy to the Pharmaceutical Society of Great Britain. 400 Engravings on Wood. 8vo, 6*s.* 6*d.*, cloth.

**Gregory's Handbook of Inorganic Chemistry.** For the use of Students. By WILLIAM GREGORY, M.D., Professor of Chemistry in the University of Edinburgh. Third Edition, revised and enlarged. 12mo, 5*s.* 6*d.*

"A young man who has mastered these few and by no means closely printed pages, may venture to face any board of examiners on Chemistry, without fear of being posed by any fair question."—*Association Journal.*

**Gregory's Handbook of Organic Chemistry;** being a New and greatly Enlarged Edition of the "Outlines of Organic Chemistry, for the Use of Students." One volume, large 12mo, 9*s.* 6*d.* cloth.

**Handbook of Organic Analysis.** By JUSTUS LIEBIG. Edited by DR. HOFMANN, Professor in the Royal College of Chemistry, London. Large 12mo. Illustrated by 85 Wood Engravings. 5*s.* cloth.

"The work now before us is a most valuable contribution to our knowledge on this most important subject. The style is lucid, and the processes are not only explained to the mind, but are made manifest to the eye by a profusion of beautiful illustrations."—*Medical Times.*

**Handbook of Inorganic Analysis.** By FRIEDRICH WÖHLER, M.D., Professor of Chemistry in the University of Gottingen. Translated and Edited by DR. HOFMANN, Professor in the Royal College of Chemistry, London. Large 12mo, 6*s.* 6*d.* cloth.

"Next to Rose of Berlin in the ranks of living analytic chemists, particularly in the inorganic department of the art, stands Friedrich Wöhler, who has in this book given us a compendium of inorganic analysis, illustrated by examples of the methods to be pursued in the examination of minerals, both of a simple and complex constitution, which, if followed out by the student with ordinary care and patience, and with some little practical instruction, will not fail to render him a thorough master of this division of chemical knowledge."—*Association Journal.*

**Elements of Chemical Analysis, Qualitative, and Quantitative.** By EDWARD ANDREW PARNELL, author of "Applied Chemistry; in Arts, Manufactures, and Domestic Economy." Second Edition, revised throughout, and enlarged by the addition of 200 pages. 8vo, Cheap Issue, 9*s.* cloth.

**Animal Chemistry; or, Chemistry in its Applications to Physiology and Pathology.** By JUSTUS LIEBIG, M.D. Edited from the Author's Manuscript, by WILLIAM GREGORY, M.D. Third Edition, almost wholly re-written. 8vo, Part I. (the first half of the work) 6*s.* 6*d.* cloth.

**Chemistry in its Application to Agriculture and Physiology.** By JUSTUS LIEBIG, M.D. Edited from the Manuscript of the Author, by LYON PLAYFAIR, Ph. D., and WM. GREGORY, M.D. Fourth Edition, revised. Cheap Issue. 8vo, 6*s.* 6*d.*

**Dyeing and Calico Printing.** By EDWARD ANDREW PARNELL, Author of "Elements of Chemical Analysis." (Reprinted from Parnell's "Applied Chemistry in Manufactures, Arts, and Domestic Economy, 1844.") With Illustrations. 8vo, 7*s.* cloth.

**Outlines of the Course of Qualitative Analysis followed in the Giessen Laboratory.** By HENRY WILL, Ph. D., Professor Extraordinary of Chemistry in the University of Giessen. With a Preface by BARON LIEBIG. 8vo, 6*s.*, or with the Tables mounted on linen, 7*s.*

**Turner's Elements of Chemistry.** Edited by Professors LIEBIG and GREGORY. Eighth Edition. 1 Vol. 8vo, 1*l.* 10*s.*

## COMMON-PLACE BOOKS AND LITERARY DIARIES.

**THE Private Diary.** Arranged, Printed, and Ruled for receiving an account of every day's employment for the space of one year. With an Index and Appendix. Cheaper Edition. Post 8vo, strongly half-bound, 3*s.* 6*d.*

**The Student's Journal.** Formed on the plan of the "Private Diary." Cheaper Edition. Post 8vo, strongly half-bound, 3*s.* 6*d.*

**The Literary Diary;** or Complete Common-Place Book, with an Explanation and an Alphabet of Two Letters on a Leaf. Cheaper Edition. Post 4to, ruled throughout, and strongly half-bound, 8*s.* 6*d.*

**A Pocket Common-place Book.** With LOCKE'S Index. Cheaper Edition. Post 8vo, strongly half-bound, 6*s.* 6*d.*

## DRAWING, &c.

**LINEAL Drawing Copies for the Earliest Instruction.** Comprising 200 subjects on 24 sheets, mounted on 12 pieces of thick pasteboard. By the Author of "Drawing for Young Children." In a portfolio. 5*s.* 6*d.*

**Easy Drawing Copies for Elementary Intruction.** By the Author of "Drawing for Young Children" Set I. Twenty-six Subjects mounted on pasteboard. Price 3*s.* 6*d.*, in a Portfolio. Set II. Forty-one Subjects mounted on pasteboard. Price 3*s.* 6*d.*, in a Portfolio.

*** The Work may also be had (two sets together) in one Portfolio, price 6*s.* 6*d.*

**Drawing Models.** Consisting of Forms for Constructing various Buildings, Gateways, Castles, Bridges, &c. The Buildings will be found sufficiently large to be drawn from by a numerous Class at the same time. In a Box, with a small Treatise on Drawing and Perspective. Price 2*l.* 10*s.* Length of the Box, 18½ inches; breadth 13 inches; height 8½ inches.

**Drawing Materials.** A Quarto Copybook of 24 leaves, common paper, 6d. A Quarto Copybook of 24 leaves, paper of superior quality, 1*s.* 3*d.* A Quarto Copybook of 60 leaves, 1*s.* 6*d.* Pencils, with very thick lead, B.B.B. 2*s.* per half dozen. Pencils, with thick lead, F. at 1*s.* 6*d.* ditto. Drawing Chalk, 6*d.* per dozen sticks, in a Box. Port-crayons for holding the Chalk, 4*d.* each.

**Perspective.** Its Principles and Practice. By G. B. Moore. In two parts, Text and Plates. 8vo, cloth, 8*s.* 6*d.*

**The Principles of Colour applied to Decorative Art.** By G. B. Moore, Teacher of Drawing in University College, London. Fcap., 2*s.* 6*d.*

## SINGING.

**THE Singing Master.** People's Edition. (One-Half the Original Price.) Sixth Edition. 8vo. 6*s.*, cloth lettered.

"What chiefly delights us in the *Singing Master* is the intermixture of many little moral songs with the ordinary glees. These are chiefly composed by Mr. Hickson himself; and we could scarcely imagine anything of the kind better executed. They relate to exactly the class of subjects which all who wish well to the industrious orders would wish to see imprinted on their inmost nature—contentment with their lowly but honourable lot, the blessings that flow from industry, the fostering of the domestic affections, and aspirations for the improvement of society."—*Chambers' Journal.*

*** *Sold also in Five Parts, any of which may be had separately as follows:—*

FIRST LESSONS IN SINGING AND THE NOTATION OF MUSIC. Containing Nineteen Lessons in the Notation and Art of Reading Music. 8vo, 1*s.* sewed.

RUDIMENTS OF THE SCIENCE OF HARMONY OR THOROUGH BASS. 8vo, 1*s.* sewed.

THE FIRST CLASS TUNE BOOK. A selection of thirty single and pleasing airs, arranged with suitable words for young children. 8vo, 1*s.* sewed.

THE SECOND CLASS TUNE BOOK. A selection of Vocal Music adapted for youth of different ages, and arranged (with suitable words) as two and three-part harmonies. 8vo, 1*s.* 6*d.*

THE HYMN TUNE BOOK. A selection of Seventy popular Hymn and Psalm Tunes, arranged with a view of facilitating the progress of children learning to sing in parts. 8vo, 1*s.* 6*d.*

The words without the Music may be had in three small books as follows:—
MORAL SONGS, from the First Class Tune Book. 1*d.*
MORAL SONGS, from the Second Class Tune Book, 1*d.*
HYMNS from the Hymn Tune Book, 1½*d.*

*** The Vocal Exercises, Moral Songs, and Hymns, with the Music, may also be had, printed on Cards, price Twopence each Card, or Twenty-five for Three Shillings.

BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

79

THE MUSEUM OF SCIENCE & ART.