pleasure. Toward the close of the 18th century, Benjamin Thompson, better known as Count Rumford, a native of Woburn, Mass., but in the employ of the Elector of Bavaria, proved the convertibility of force. "He first took the subject," as Professor Youmans well remarks, "out of the domain of metaphysics, where it had been speculated upon since the time of Aristotle, and placed it on the true basis of physical experiment."

Soon the scientific world seemed to be ripe for this discovery, and it appears to have sprung up spontaneously in men's thoughts every-where. Mayer, a physician of Germany, and Grove, of England, proved the mutual relation of the forces, the latter first using the term "Correlation of Forces," since changed to Conservation of Energy. Joule discovered the law of the "Mechanical Equivalent of Heat," about 1843. In his famous experiments, he used pound-weights made to fall through a measured distance. Cords were attached to them, so that, as they fell, they turned a paddle-wheel placed in a box of water. Other liquids were used instead of the water. The rise of temperature in the liquids was carefully marked. The loss by friction in the apparatus was estimated, and so, at last, the dynamical theory of heat was fully demonstrated. Names of philosophers well known to us, such as Henry, Helmholtz, Faraday, Thomson, Maxwell, Le Conte, Youmans, Stewart, and Tyndall, are associated with the final establishment of this theory.

Consult, on this interesting subject, Tait's "Recent Advances in Physical Science"; Stewart's "Treatise on Heat"; Tyndall's "Heat a Mode of Motion"; Maxwell's "Theory of Heat"; Thurston's "History of the Growth of the Steam-engine"; Buckley's "Short History of Natural Science"; Smiles' "Lives of Boulton and Watt"; Youmans' "Correlation of the Physical Forces"; "Read and the Steam-engine"; "American Cyclopedia," Art. "Steam-engine"; "Popular Science Monthly," Vol. XII., p. 616, Art. "Liquefaction of Gases"; Scott's "Meteorology," and Thomson's "Cruise of the Challenger."

conetic
potential — the power

IX.

MAGNETISM.

"NEXT in order I will proceed to discuss by what law of Nature it comes to pass that iron can be attracted by that stone which the Greeks call the Magnet, from the name of its native place, because it often produces a chain of [iron] rings hanging down from it. Thus you may see five and more suspended in succession and tossing about in the light airs, one always hanging from the other and attached to its lower side, and each in turn, one from the other, experiencing the binding power of the stone; with such a continued current, its force flies through all."

ANALYSIS OF MAGNETISM.

MAGNETISM.
1. Magnets.
2. The Magnetic Meridian.
3. Laws of Magnetism.
4. Induction.
5. How to Make a Magnet.
6. The Compass.
7. Lines of Force.
8. Polarity of the Needle.
9. Terrestrial Magnetism.

MAGNETISM.

1. Magnets.*—A natural magnet is an ore of iron (Fe_3O_4, "Popular Chemistry," p. 156), generally known

Fig. 191.

Magnet Dipped in Iron Filings.

as lodestone (Saxon, laedan, to lead), which has the power of attracting iron.† The artificial magnet is a

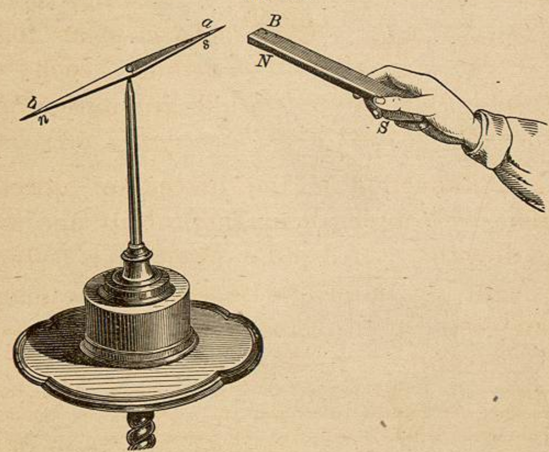
* The term is derived from the fact that an ore of iron possessing this property was first found at Magnesia, in Asia Minor.

† A few other elements, such as nickel and cobalt, are attracted

steel bar that has acquired properties like those of lodestone. If it be straight, it is called a bar magnet; if U-shaped, a horseshoe magnet. A piece of soft iron called the *armature* is placed so as to connect the two ends of the horseshoe.

If we insert a magnet in iron filings, they will cling chiefly to its ends termed the *poles*. The magnetic force will be exerted even through any intervening body that is not itself magnetic.

Fig. 192.



Influence of one Magnet on another.

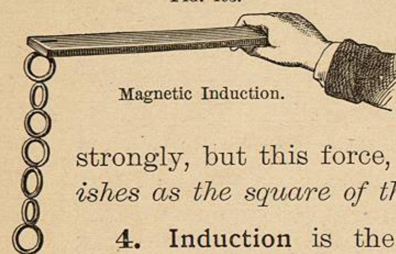
2. The Magnetic Meridian.—If a slender bar magnet be suspended or pivoted properly, so as to swing freely in a horizontal position, one pole will point toward the neighborhood of the north and the other in the opposite direction. The former is called

slightly by the magnet. They are all called magnetic bodies, but for ordinary purposes iron may be regarded as the only one of importance.

the north, or positive (+) pole, and the latter the south, or negative (−) pole. A magnet thus poised constitutes a *magnetic needle*.

3. Laws of Magnetism.—If we hold a magnet near a magnetic needle, we shall find that the south pole of one attracts the north pole, and repels the south pole of the other.* This proves the law—"*Like poles repel, and unlike poles attract.*"

Fig. 193.



Magnetic Induction.

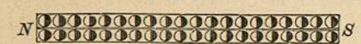
Two opposite poles placed near together attract each other strongly, but this force, like gravitation, *diminishes as the square of the distance increases.*

4. Induction is the process of developing magnetism by bringing a magnetic body and a magnet near together. If a piece of soft iron be brought near a magnet, it immediately assumes the magnetic state, but loses it on being removed. In steel the

* *Experiments.*—1. Rub the point of a sewing-needle across the north pole of a magnet. Bring the point near the south pole of the magnetic needle. The needle will be repelled, showing that the point of the sewing-needle has become a south pole. 2. Suspend a key from the north pole of a magnet. Bring the south pole of an equal magnet close to the upper end of the key. The key will instantly fall. 3. Suspend a long iron wire from the north pole of a magnet. Bring the north pole of the second magnet near the lower end of the wire. The wire is repelled, because its lower extremity possesses north polarity. 4. Immerse the unlike poles of two magnets in iron filings. Bring the two poles near each other. The filings will move toward one another. But if the poles of the magnets are like, the filings will fall off the magnets. 5. To ascertain whether a metallic substance contains iron: Bring the substance near one of the extremities of a magnetic needle. If the position of the needle be affected, then the substance almost certainly contains iron. A piece of copper will not affect the magnetic needle.

change is induced and lost much more slowly. The end of the bar next to the south pole of the magnet becomes the north pole of the new magnet, and *vice versa.* When opposite states are thus developed in the opposite ends of a body, it is said to be *polarized.* Whenever an object is attracted by a magnet, it is supposed first to be made a magnet (polarized) by induction, and then the attraction consists in that of unlike poles for each other. Thus we may suspend from a magnet a chain of rings held together by magnetic attraction.* Each link is a magnet with its north and south poles. Each particle of the tuft of filings in Fig. 191 is a distinct magnet. By inducing magnetism, a magnet does not lose force. It rather gains by the reciprocal influence of the new magnet. An armature acts in this manner to strengthen a magnet. If we break a magnet, the smallest fragment will have a north and a south pole. This is explained by supposing that every molecule contains two opposite kinds of energy which neutralize each other. When the bar is magnetized these are separated, but do not leave the molecule. This is hence polarized, the halves assuming opposite magnetic states, as shown in Fig. 194. The light half of each little circle represents the positive, and the dark the negative side. All the molecules exert their negative force in one direction, and their positive in

Fig. 194.

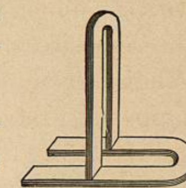


Polarization of an Iron Bar.

* Repeat this experiment with keys, or nails of different sizes, or bits of wire of varying length.

the other. The forces thus neutralize each other at the center, but manifest themselves at the ends of the magnet. Hence it is impossible to produce a magnet with only one pole. Each pole necessitates the presence of the other.

Fig. 195.



Making a Magnet.

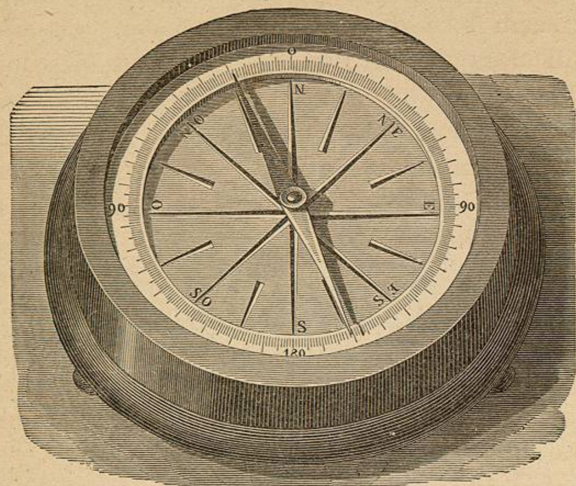
5. How to Make a Magnet.—Place the inducing magnet, as shown in Fig. 195, on the unmagnetized bar (which any blacksmith can make from a bar of steel), and draw it from one end to the other several times, always carrying it back through the air to the starting-point.*

6. The Compass is a magnetic needle used by mariners, surveyors, etc. It is delicately poised over a card on which the "points of the compass" are marked. At most places the needle does not point directly N. and S. The "*line of no variation*" in the United States passes near Wilmington, N. C., Charlottesville, Va., and Pittsburg, Pa. East of this the declination of the needle from true north is toward the west, and west of it the declination is toward the east.

7. Lines of Force.—The region in the neighborhood of a magnet pole within which it can have a perceptible effect upon magnetic bodies is called its

* A needle may be magnetized by laying it across the poles of a horseshoe magnet. After remaining a few hours, the end in contact with the north pole of the magnet will become a south pole and the other a north pole. If it be suspended from the middle by a thread, it will point north and south. A knife-blade may be magnetized by rubbing it several times, in the same direction, across one of the poles of the magnet.

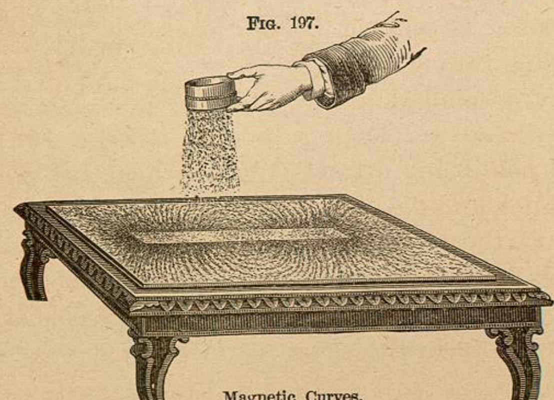
Fig. 196.



The Compass.

field. The directions which these bodies tend to assume are called *lines of force.* Over a bar magnet lay a sheet of paper or a plate of glass, and sprinkle fine iron filings over this. On gently tapping the

Fig. 197.



Magnetic Curves.

plate they become arranged in curved lines, many of which seem to radiate from the poles. These are the indicators of the lines of force, the position of each iron filing being determined by its direction and distance from the two poles of the magnet.

Between the two opposite poles of a horseshoe magnet, or of two separate magnets brought near together, the lines of force are straight.

8. Polarity of the Needle.—Why the Needle points North and South.—The earth is a great magnet, whose opposite poles produce lines of force that permeate its body and the space around. A needle when magnetized tends to assume the direction of the line of force that passes through it. The position of the terrestrial magnetic poles is not constant, and hence the needle changes its direction accordingly.

Fig. 198.

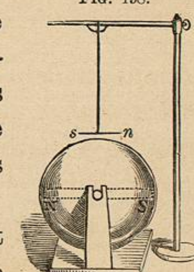
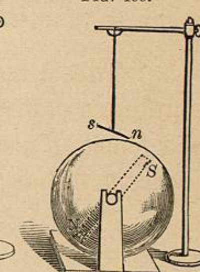


Fig. 199.



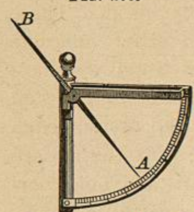
Magnet in Globe.

Suppose a magnet *NS* passing through the center of a small globe. The needle *sn* will hang parallel to it (Fig. 198), its positive pole being attracted by the negative pole of the magnet, and *vice versa.* If the globe be revolved (Fig. 199), the positive pole of the needle will turn—*dip*, as it is termed—downward. If the globe be revolved in the other direction, the negative pole of the needle will dip in the same manner.*

* Similar phenomena are noticed in the compass. At the magnetic

A DIPPING-NEEDLE is poised as shown in Fig. 200. At the magnetic equator it hangs horizontally, but when carried north its positive end dips downward more and more until it points vertically downward at a point in Boothia Peninsula, north of Hudson Bay, called the *pole of verticity*, or often simply the magnetic pole. This is the *negative* pole of the earth. The position of its positive pole has been calculated to be beneath the Antarctic Ocean.*

FIG. 200.



The Dipping-needle.

9. Magnetism of the Earth.—All iron bars standing vertically (in this latitude not far from the line of the dip) possess slight magnetic properties. Iron fences, lightning-rods, iron standards of chairs and desks, pokers, tongs, crow-bars, etc., on being tested by the magnetic needle, will be found to possess positive polarity in the end next the ground, and negative polarity in the other.

The cause of the earth's magnetism and of the variations in it is not yet known.

equator it is horizontal, but *dips* whenever taken north or south. An unmagnetized needle, if poised, in our latitude, on being magnetized, settles down, as if the north end were the heavier. This is remedied by making the north end of the needle lighter, or by attaching a little weight upon the south end. The reverse is true in the southern hemisphere.

* The declination and dip of the magnetic needle have daily and yearly variation, and also very slow changes requiring centuries to complete. In 1686, at New York, the declination was 9° west; in 1750, 6° 20′ west; in 1790, 4° 15′ west; in 1847, 6° 30′ west; in 1885, 8° west. The line of no variation was becoming slowly shifted eastward from 1686 to 1790, then became stationary, and has since been moving westward. The intensity of terrestrial magnetism at any given place has also daily variations, growing stronger by day and weaker by night.

SUMMARY.

NATURAL magnets are found in certain regions, but in practice, magnets made of steel are generally used. These bars may be magnetized either by contact with other magnets or by placing them within the magnetic field of a coil conducting an electric current (see p. 332). The existence of magnetism is manifested by polarity. Like poles repel, unlike attract each other. The intensity of the force varies inversely as the square of the distance. A magnet induces magnetism in any neighboring magnetic body. This is not prevented by intervening bodies which are not themselves magnetic. If free to move, small bodies thus influenced by induction tend to place themselves in certain directions, called lines of force, around the inducing magnet. The declination, the dip, and the intensity are the magnetic elements of a place. Each of these is subject to daily variations, and additionally to slow changes requiring many years for a cycle. The cause of the earth's magnetism is unknown. Sudden variations in it accompany the outbreak of spots on the sun, and magnetic storms are usually attended by the appearance of the aurora.

HISTORICAL SKETCH.

MAGNETS probably became first known to European nations through the discovery of natural magnets by the Greeks in the Thessalian district of Magnesia. From this the name was taken. The tendency of a magnetized needle to point in a definite direction was early noticed, and it is thought that the compass was invented by the Chinese. The first mention of the use of the magnetic needle in Europe occurs in 1190. The needle was floated on a cork, and in this way it served as a guide to the Chinese travelers. By the end of the fifteenth century the compass was known to most European sailors, and its use was specially frequent among the Spanish and Portuguese. The declination of the needle was known to the Chinese in the beginning of the twelfth century. Columbus discovered it independently in 1482, just ten years before his discovery of America. The first known work for the use of seamen was written during the reign of Queen Elizabeth. It was entitled "A Discourse on the Variation of the Cumpas or Magneticall Needle," and is dedicated to "the travaillers, sea-men, and mariners of England." The dip was discovered accidentally in 1576 by Robert Norman, an English instrument-maker. He found the dip at London to be 71° 50′. Dr. Gilbert, the physician of Queen Elizabeth, published his great work, "De Magnete," about 1600. In this he announces his belief that the earth is a great magnet, controlling the direction of the needle. The variation in intensity of the earth's magnetic force has become known chiefly during the present century.

X.

ELECTRICITY.

"That power which, like a potent spirit, guides
The sea-wide wanderers over distant tides,
Inspiring confidence where'er they roam,
By indicating still the pathway home;—
Through Nature, quickened by the solar beam,
Invests each atom with a force supreme,
Directs the cavern'd crystal in its birth,
And frames the mightiest mountains of the earth,
Each leaf and flower by its strong law restrains,
And binds the monarch Man within its mystic chains."

HUNT