applied or withdrawn. We can not conceive this to be possible if they are in perfect contact.

5. Indestructibility is the property which renders matter incapable of being destroyed. We can not conceive of the annihilation of matter. We may change its form, but we can not deprive it of existence.—*Example:* We cut down a tree, saw it into boards, and build a house. The house burns, and only little heaps of ashes remain. Yet in the ashes, and in the smoke of the burning building, exist the identical atoms, which have passed through these various forms unchanged.*

III. SPECIFIC PROPERTIES OF MATTER.

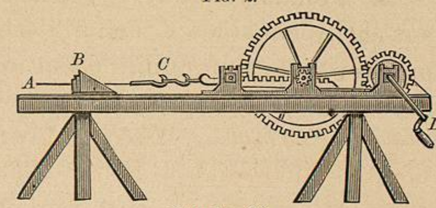
Among the most important specific properties of matter are ductility, malleability, tenacity, elasticity, hardness, and brittleness.

1. Ductility.—A ductile body is one which can be drawn into wire. Fig. 2 represents a machine for making wire. *B* is a steel drawing-plate pierced with a series of gradually diminishing holes. A rod of iron, *A*, is hammered at the end so as to pass

* Walter Raleigh, while smoking in the presence of Queen Elizabeth, offered to bet her majesty that he could tell the weight of the smoke that curled upward from his pipe. The wager was accepted. Raleigh quietly finished, and then weighing the ashes, subtracted this amount from the weight of the tobacco he had placed in the pipe, thus finding the weight of the smoke. When we reach the subject of combustion in chemistry, we shall be able to detect Raleigh's mistake. The smoke and the ashes really weighed more than the original tobacco. since the oxygen of the air had combined with the tobacco in burning.

through the largest. It is then grasped by a pair of pincers, *C*, and, by turning the crank, *D*, is drawn through the plate, diminished in diameter and proportionately increased in length. The tenacity of the metal is greatly improved by the process of drawing, so that a cable of fine wire is stronger than a chain or bar of the same weight. Gold, silver, and platinum are the most ductile metals. A silver rod an inch thick, covered with gold leaf, may be drawn to the fineness of a hair and yet retain a perfect coating of gold, three ounces of the latter metal making 100 miles of the gilt-thread used in embroidery. Platinum wire has been drawn so fine that, though it is nearly three times as heavy as iron, a mile's length weighed only a grain.

Fig. 2.



Drawing Wire.

2. Malleability.—A malleable body is one which can be hammered or rolled into sheets.—*Example:* Gold may be beaten until it is only $\frac{1}{360\,000}$ of an inch thick. It would require 1,800 such leaves to equal the thickness of common printing-paper.* Copper is

* An ingot of gold is passed many times between steel rollers, which are so adjusted as to be continually brought nearer together. The metal is thus reduced to a ribbon about $\frac{1}{800}$ of an inch thick. This is cut into inch squares, 150 of which are piled up alternately with leaves of strong paper four inches square. A workman with a hammer beats the pile until the gold is spread to the size of the leaves. Each piece is next quartered, and the 600 squares are placed between leaves of goldbeaters'

so malleable, that a workman can hammer out a kettle from a solid block.

3. Tenacity.—A tenacious body is one which can not easily be pulled apart. Iron possesses this quality in a remarkable degree. Steel wire will sustain many thousand times its own weight.

4. Elasticity is of four kinds, according as a body tends to resume its original form when *compressed*, *extended*, *twisted*, or *bent*.

(1.) Elasticity of Compression.—Many *solids*, as iron, glass, and caoutchouc, are highly elastic.—*Example:* Spread a thin coat of oil on a smooth marble slab. If an ivory ball be dropped upon it, the size of the impression will vary with the distance at which the ball is held above the table. This shows that the ivory is flattened, somewhat like a soap-bubble when it strikes a smooth surface and rebounds.

Fig. 3.

Elasticity of Ivory.

Liquids are compressed with great difficulty, so that for a long time they were considered incompressible. When the force is

skin and pounded. They are then taken out, spread by the breath, cut, and the 2,400 squares pounded as before. They are finally trimmed and placed between tissue-paper in little books, each of which contains twenty-five gold leaves.

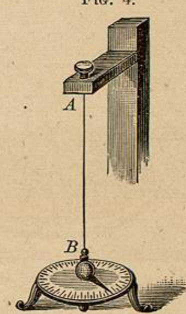
removed, they regain their exact volume, and are therefore perfectly elastic.

Gases are easily compressed, and are also perfectly elastic. A pressure of 15 lbs. to the square inch reduces the volume of water only $\frac{1}{20000}$, whereas it diminishes the volume of a perfect gas $\frac{1}{2}$. A gas may be kept compressed for years, but on being released will instantly return to its original form.

(2.) Elasticity of Expansion is possessed largely by very many substances.—*Examples:* India rubber, when stretched, tends to fly back to its original dimensions. A drop of water hanging to the nozzle of a bottle may be touched by a piece of glass and drawn out to considerable length, but when let go it will resume its spherical form.

(3.) Elasticity of Torsion is the tendency of a thread or wire which has been twisted, to untwist again. If a weight be suspended by means of a steel wire, twisted around and then released, it constitutes a torsion pendulum. (Fig. 4.)

Fig. 4.



The Torsion Pendulum.

(4.) Elasticity of Flexure is the property ordinarily meant by the term elastic. Many solids possess this quality, within certain limits, to a high degree. Swords have been made which could be bent into a circle without breaking. Watch-springs, bows, cushions, etc., are useful because of their elasticity. Glass, though brittle, is one of the most elastic substances known.

5. Hardness.—One body is harder than another when it will scratch or indent it. This property does not depend on density.*—*Examples:* Gold is about 2½ times as dense as iron, yet it is much softer.—Mercury is a liquid, yet it is almost twice as dense as steel.—The diamond is the hardest known substance, yet it is not one third as heavy as lead.

6. Brittleness.—A brittle body is one that is easily broken. This property is a frequent characteristic of hard bodies.—*Example:* Glass will scratch pure iron, yet it is extremely brittle.

SUMMARY.

MATTER is that which occupies space. A separate portion is called a body, and a particular kind a substance. A general property of matter belongs to all substances, and a specific one to particular kinds. Matter is composed of very minute atoms. A group of atoms forms a molecule, in which reside the specific properties of a substance. A physical change never affects the molecule, but a chemical change breaks it up, and so makes new combinations possible. Physics deals with physical forces and changes; Chemistry with chemical attraction, and chemical changes. Extension and impenetrability are the essential properties of matter. Extension is the property of occupying space. The amount of space a body fills is its volume. In virtue of impenetrability two bodies can not occupy the same space at the same time. The divisibility of matter is without perceptible limit so far as we know. Porosity is the property in virtue of which the molecules of a body are not in absolute contact. Indestructibility prohibits the extinction of matter by man. Ductility, malleability, tenacity, elasticity, hardness, and brittleness are the principal specific properties of matter. A ductile body can be drawn into wire; gold, silver, and platinum are the most noted for this property. A malleable body can be hammered into sheets; gold possesses this quality in a remarkable degree. A tenacious body resists pulling apart; iron is the best example. An elastic body permits a play of its particles, so that they return to their original position when the disturbing force is removed. A hard body can not easily be indented. A brittle body is readily broken.

* A *dense* body has its molecules closely compacted. The word *rare*, the opposite of dense, is applied to gases. *Mass*, or the quantity of matter a body contains, should be distinguished from weight or size.

HISTORICAL SKETCH.

IN ancient times, any seeker after truth was termed a philosopher (a lover of wisdom), and philosophy included all investigations concerning both mind and matter. In the fourth century B. C., Plato assumed that there are two principles, matter and form, which by combining produce the five elements, earth, air, fire, water, and ether. Aristotle, his pupil, established the first philosophical ideas concerning matter and space. But the method of study generally pursued for 2,000 years was one of pure metaphysical speculation. Observation had no place, but the philosophers made up a theory, and then accommodated facts to it. They guessed about the real essence of things, as to whether matter exists except when perceived by the mind,* and how a change in matter can produce a change in mind. In 1620, Bacon published his "Novum Organum," advocating the inductive method of studying nature. He argued that the philosopher should seek to benefit mankind, and that, instead of wasting his time in sterile and ingenious theories about the world and matter, he should watch the phenomena of life, gather facts, and then reasoning from effects back to their causes, reach the general law. This work

* Dr. Johnson once remarked to a gentleman who had been defending the theory that there is no external world, as he was going away, "Pray, sir, don't leave us, for we may perhaps forget to think of you, and then you will cease to exist."

is commonly said to have established the modern method of investigation. Ptolemy, Archimedes, Galileo, and other physicists, however, had long before proved its value.

The Atomic Theory was propounded by Democritus, in the fifth century B. C., and twenty-two centuries later elaborated by Dalton, an English physicist. The grander generalization and development of this law was advanced in 1811 by Avogadro, an Italian, and afterward extended by the French philosopher, Ampere. The latter asserted that "equal volumes of all substances, when in the gaseous form and under like conditions, contain the same number of molecules." For half a century this view lay dormant. Of late it has borne fruit, and the molecular theory has become to Chemistry what the law of gravitation is to Astronomy. The labors of Thomson, Cooke, Tait, and others are now building up the whole superstructure of Chemistry and Physics upon this basis.

The history of the establishment of a standard of measures is a curious one. Anciently, length was referred to some portion of the human body, as the foot; the cubit (the length of the fore-arm from the elbow to the end of the middle finger); the finger's length or breadth; the hand's breadth; the span, etc. In England, Henry I. (1120) ordered that the ell, the ancient yard, should be the exact length of his arm. Afterward a standard yard-stick was kept at the Exchequer in London; but it was so inaccurate, that a commissioner, who examined it in 1742, wrote: "A kitchen poker filed at both ends would make as good a standard. It has been broken, and then repaired so clumsily that the joint is nearly as loose as a pair of tongs." In 1760, Mr. Bird carefully prepared a copy of this for the use of the government. It was not legally adopted until 1824, when it was ordered that if destroyed, it should be restored by a comparison with the length of a pendulum vibrating seconds at the latitude of London. At the great fire in London, 1834, the Parliament House was burned, and with it Bird's yard-stick. Repeated attempts were then made to find the length of the lost standard by means of the pendulum. This was found impracticable, on account of errors in the original directions. At last the British government adopted a standard prepared from the most reliable copies of Bird's yard-stick. A

copy of this was taken by Troughton, an instrument-maker of London, for the use of our Coast Survey.*

The French had previously adopted for the length of the legal foot that of the royal foot of Louis XIV., as perishable a standard as Henry's arm. In 1790, the Prince de Talleyrand proposed to the Constituent Assembly of France the foundation of a system based on a single and universal standard, which might be used by all civilized nations. The selection of this was committed to five members of the Academy of Sciences, MM. Borda, Lagrange, Laplace, Monge, and Condorcet, who decided that the ten-millionth part of a quarter of the earth's meridian should be taken as the standard of length, from which the standards of surface, volume, capacity, and weight should be derived. A trigonometric measurement was made of the arc of a meridian extending through France from Dunkirk to Barcelona, a work which occupied seven years. In 1799, an international commission was assembled at Paris, with representatives from most of the governments of Europe. They deposited at the Palace of the Archives, in Paris, the standard meter-bar of platinum, and the standard kilogram weight, made of the same metal. In English denominations the length of the meter is almost exactly 3.28 feet, or 39.37 inches; the weight of the kilogram almost exactly 2.2 pounds avoirdupois.

But after the establishment of the metric system it was found that a slight mistake had been made in the measurement of the arc of the meridian. The English, who had declined to accept the French system, discovered also a difficulty in the determination of the yard from the pendulum beating seconds Both the yard and the meter are therefore arbitrary and not absolute standards. Copies of each have been made so carefully and distributed so widely that there is no probability of any appreciable loss resulting from the accidental destruction of the originals. The metric system is by far the simplest and best in use, but it has not yet generally supplanted other sys-

* A bronze bar, which has the standard length at 61.79° F., has been presented by the English government to that of the United States. According to Act of Congress, sets of weights and measures have been distributed to the governors of the several States. Both the yard and the meter are legal standards in the United States and Great Britain.

tems that retain their popularity, not on account of merit, but only because of human conservatism and the inconveniences resulting from change.

Consult Cooke's "New Chemistry," chapter on Molecules, etc.; Powell's "History of Natural Philosophy"; Buckley's "History of Natural Science"; Whewell's "History of the Inductive Sciences"; Roscoe's "John Dalton and his Atomic Theory," in Manchester Science Lectures, '73–4; "Appleton's Cyclopedia," Art. Molecules; Outerbridge's "Divisibility of Gold and Other Metals," in Popular Science Monthly, Vol. XI., p. 74; Crookes' "The Radiometer—a fresh evidence of a Molecular Universe," Popular Science Monthly, Vol. XIII., p. 1; Tait's "Recent Advances in Physical Science," Chap. XII., The Structure of Matter; Hoefer, "Histoire de la Physique et de la Chimie"; Draper's "History of Intellectual Development of Europe"; Barnard on "The Metric System."

II.

MOTION AND FORCE.

Rest is nowhere. The winds that come and go, the ocean that uneasily throbs along the shore, the earth that revolves about the sun, the light that darts through space—all tell of a universal law of Nature. The colidest body hides within it inconceivable velocities. Even the molecules of granite and iron have their orbits as do the stars, and move as ceaselessly.

No energy is ever lost. It changes its form, but the eye of philosophy detects it and enables us to drive it from its hiding-place undiminished. It assumes Protean guises, but is every-where a unit. It may disappear from the earth; still—

"Somewhere yet that atom's force
Moves the light-poised universe."