6. The falling of a stone? The growth of a tree?
7. The flying of a kite? The chopping of wood?
8. The explosion of powder? The boiling of water?
9. The melting of iron? The drying of clothes?
10. The freezing of water? The dissolving of sugar?
11. The forging of a nail? The making of bread?
12. The sprouting of a seed? The decay of vegetables?
13. The condensation of steam?

II. GENERAL PROPERTIES OF MATTER.

THERE are two essential properties without which matter is inconceivable. These are extension and impenetrability.

1. Extension is the property of occupying space. The amount of space a body occupies is called its *volume.*

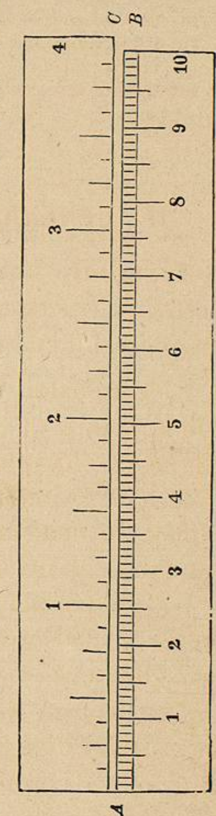
Measurement of Extension.—A body has three dimensions: length, breadth, and thickness. To measure these, some standard is required. The standard of length popularly in use in England and the United States is the yard. Its length is the distance between two lines on a certain bar of bronze, kept in London and measured at a certain temperature, 62° F. (see p. 248). There is only one yard in the world; all that we call yards are imperfect copies from it. The yard is inconveniently divided into three feet, or thirty-six inches. The standard of length used in France, and by scientific men throughout the world, is the meter.* Its length is nearly, but not exactly,

* The meter is divided into ten decimeters (*dm.*); each of these into ten centimeters (*cm.*); and each of these into ten millimeters (*mm.*). In Fig. 1 is

$\frac{1}{40\,000\,000}$ of an entire meridian of the earth. There is only one meter in the world. It is the length of a certain bar of platinum, kept in Paris, and measured at the temperature of melting ice. Most copies of the meter and yard are accurate enough for the purposes to which they are applied.

2. Impenetrability is the property of so occupying space as to exclude all other matter.* No two bodies can occupy the same space at the same time. A book lies upon the table before me; no human power is able to place another in the same spot, until the first book

FIG. 1.



Comparison of Metric and English Measures of Length.

shown a line, *AB*, whose length is a decimeter, divided into centimeters and millimeters. At the side of it is another line, *AC*, slightly longer. It is made up of four inches, divided into halves, quarters, and eighths. The length of the meter is about 39.37 inches, or nearly 1.1 yard.

For the measurement of surface, we use square meters (*sq. m.*), square centimeters (*sq. cm.*), etc.

The unit adopted for the measurement of volume is the cubic decimeter. It is called a *liter.* A vessel that contains just a liter of water will hold a little more than a quart of the same liquid. Since the liter has a length, breadth, and thickness of one decimeter, it contains 1,000 cubic centimeters.

* In common language, we say a needle penetrates cloth, a nail enters wood, etc.; but a moment's examination shows that they merely push aside the fibers of the cloth or wood, and so press them closer together. With care we can drop a quarter of a pound of shingle-nails into a tumbler brimful of water, without causing it to over flow. The surface of the water, however, becomes convex.

is removed. I attempt to fill a bottle through a closely-fitting funnel; but before the liquid can run in, the air must gurgle out, or the water will trickle down the outside of the bottle.

In addition to these two essential properties of matter, there are others which have been found to be general, such as divisibility, porosity, and indestructibility.

3. Divisibility is that property by which a body may be separated into parts. The extent to which the divisibility of matter may be carried is almost incredible.*—*Example:* A grain of strychnine will flavor 1,750,000 grains of water; hence there will be in each grain of the liquid only $\frac{1}{1\,750\,000}$ of a grain of strychnine, yet this amount can be distinctly tasted.

4. Porosity is the property of having pores. By this is meant not the *sensible* pores to which we refer when in common language we speak of a porous body, as bread, wood, unglazed pottery, a sponge, etc., but the finer or *physical* pores. The latter are as invisible to the eye as the atoms themselves, and are caused by the fact that the molecules of which a body is composed are not in actual contact, but

* Newton estimated that the film of a soap-bubble at the instant of breaking is less than $\frac{1}{2\,500\,000}$ of an inch thick. Pure water will acquire the requisite viscidity for making bubbles by adding only $\frac{1}{100}$ part of soap. It is evident that there must be at least one molecule of soap in every cubic $\frac{1}{2\,500\,000}$ of an inch of the film, and that the molecule must be smaller than one hundredth of a cubic $\frac{1}{2\,500\,000}$ of an inch, *i. e.*, than $\frac{1}{250\,000\,000}$ of a cubic inch. Now a molecule of soft-soap (if it is a pure potassium stearate, "Chemistry," p. 207) contains 56 atoms, and this point must be reached before we come to the possible limit of divisibility.

are separated by minute spaces.*—*Examples:* To a bowl-full of water it is easy to add a quantity of fine salt without the liquid running over. Only care must be taken to drop in the salt slowly, giving time for it to dissolve and the bubbles of air to pass off. When the water has dissolved all the salt it can, we can still add other soluble solids.†—In testing large cannon by hydrostatic pressure (p. 104), water is forced into the gun until it oozes through the thick metal and covers the outside of the gun like froth, then gathers in drops and runs to the ground in minute streams.‡

It is in virtue of these physical pores that a body changes in volume when warmed or cooled. The molecules become farther apart or nearer as heat is

* These spaces are so small that they can not be discerned with the most powerful microscope, yet it is thought that they may be very large when compared with the size of the atoms themselves. If we imagine a being small enough to live on one of the atoms near the center of a stone, as we live on the earth, then we are to suppose that he might possibly see the nearest atoms at great distances from him, as we see the moon and stars, and might perchance have need of a fairy telescope to examine them, as we investigate the heavenly bodies. It is impossible, however, for us to have any definite knowledge on such a topic.

† In this case we suppose that the particles of salt are smaller than those of water, and those of the different substances used are smaller than those of salt. The particles of salt fill the spaces between the particles of water, and the others occupy the still smaller spaces left between the particles of salt. We may better understand this if we suppose a bowl filled with oranges. It will hold a quantity of peas, then of gravel, then of fine sand, and lastly some water.

‡ In the course of some experiments performed during the eighteenth century at the Florence Academy, Italy, hollow globes of silver were filled with water and placed in a screw-press. The spheres being flattened, their size was diminished, and the water oozed through the pores of the metal. The philosophers of the day thought this to show that water is incompressible. We now see that it proved only that silver has pores larger than the molecules of water.

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.

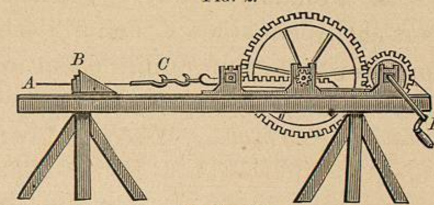
Among the most important specific properties of matter are ductility, malleability, tenacity, elasticity, hardness, and brittleness.

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 $\frac{1}{360000}$ 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'