for that year. By taking the sum of the mean annual heights for many years and dividing it by the number of years, the result is *the mean height* for that place.

At the level of the sea, the mean height is not far from 30 inches, as already stated.

Causes of Barometrical Fluctuations.

114. The cause of the fluctuations observed in the barometer, is a change in the weight of the column of air above it. Since the weight of the entire atmosphere is constant, if it become heavier at one point on the earth's surface, it must become lighter at some other point; a fact which is confirmed by observations by means of the barometer.

The cause of the change of weight in the column of air over the barometer, is a change of temperature. When the temperature at any place is elevated, the air expands and rises upward until its lateral tension is greater than that of the surrounding air, when it flows away to the neighboring regions. When, on the contrary, the temperature is diminished, the air contracts and an additional quantity flows in from the neighboring regions.

The barometer, then, falls where there is a dilatation, and rises where there is a contraction, of the air.

The barometer serves as a weather-glass. It stands high in fair weather, and low in foul weather. A sudden fall of the barometer indicates an approaching storm, and a sudden rise, in general, indicates approaching fair weather.

The Index Barometer.

115. Fig. 78 represents an ornamental form of an Index Barometer. The manner in which the index is made to show the

For any place? What is the mean height at the level of the sea? (**114**) What is the cause of the fluctuations observed? What is the cause of the change of weight in the aerial column? When does the barometer rise? Fall? *Use of the barometer as a weather-glass?* (**115.**) *Explain the Index barometer.*

fluctuations of the barometer, is shown in Fig. 79. The index is attached to an axis which bears a pulley. Passing over this pulley is a fine wire, at one extremity of which is attached an iron weight,

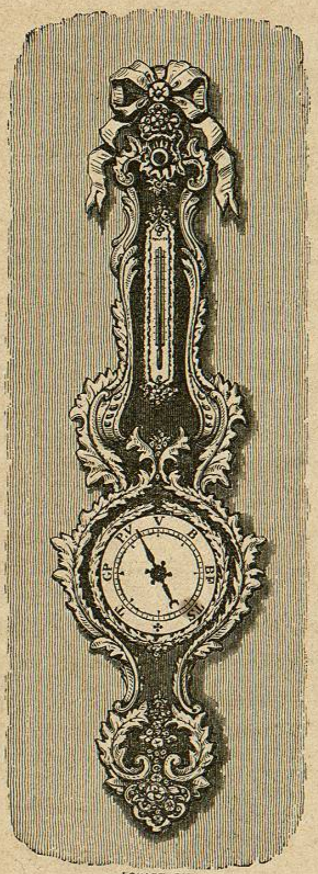

Fig. 78.

Fig. 79.

a, which rises when the height of the mercury diminishes, and falls when this height increases. At the second extremity is a counterpoise, *b*, which keeps the wire tense, and causes the wheel to turn as the weights rise and fall.

The index plays in front of a dial-plate, around which are marked certain letters indicating the weather to be expected when the index stands at any one of them. The instrument shown in the figure is of French construction, and the letters are the initials of the French names of the different kinds of weather, as exhibited below. In the annexed table is shown the height of the barometer corresponding to each indication:

TABLE.

HEIGHT OF BAROMETER.	LETTERS.	FRENCH.	ENGLISH.
28.78 inches.	T.	Tempête.	Tempest.
29.13 "	G. P.	Grande pluie.	Heavy rain.
29.48 "	P. V.	Pluie ou vent.	Rain or wind.
29.84 "	V.	Variable.	Variable.
30.19 "	B.	Beau temps.	Fine weather.
30.54 "	B. F.	Beau fixe.	Settled weather.
30.90 "	T. S.	Très-sec.	Drought.

The above table is only given to illustrate the method of employing the instrument. It is evident that different tables would be required at different places. But little reliance is to be placed on barometers of this kind, as weather indicators.

Measure of Mountain Heights by the Barometer.

116. One of the most important applications of the barometer, is to the measurement of the height of any place above the level of the sea.

As we ascend above the level of the sea, the pressure of the air diminishes, and the barometer falls. Formulas have been deduced, by means of which the difference of level between any two places can be found, when we have the heights of the mercurial columns at the two places, together with the temperatures of the air and mercury at these places.

A detailed explanation of the method of making the observations,

Its construction and use. (**116.**) *On what principle is the barometer used for measuring heights?*

and deducing the difference of level, does not come within the plan of this work. For information on this subject, the reader is referred to Mechanics, Art. 200.

Height of the Atmosphere.

117. The density of the air at the surface of the earth is about 10,400 times less than that of mercury. Were there no decrease in density as we ascend, its height would be 10,400 times 30 inches, or 26,000 feet; that is, about five miles. But on account of the rapidly decreasing density upwards, the actual height is very much greater. It has been estimated to be not far from forty-five miles in height.

Atmospheric Pressure transmitted in all directions.

118. Gases, as well as liquids, transmit pressures in all directions, from which it results that the pressure of the air is not only felt downwards, but laterally in all directions. This is shown by the Magdebourg hemispheres, which adhere with equal force, whether the force to draw them asunder be exerted vertically, laterally, or in any oblique direction.

The same fact may be illustrated as follows: Let a tumbler be filled with water, and covered with a sheet of paper; then, holding the paper in contact with the water, let the tumbler be inverted. If the hand be withdrawn, the water remains in the tumbler, being held there by the pressure of the atmosphere, directed upwards, as shown in Fig. 80.

The wine-taster, shown in Fig. 81, is constructed on this principle. It consists of a tube open at both ends, the lower opening being quite small. The instrument is introduced into a cask of

(**117.**) Were the density the same as at the earth's surface, what would be its height? What is its estimated height? (**118.**) How are pressures transmitted through gases? How is the principle illustrated? *What is the principle of the wine-taster?*

wine through the bung-hole, and when it has become filled to the level of the liquor in the cask, the thumb is placed over the upper end, and the instrument is withdrawn. A portion of the wine is

Fig. 80.

Fig. 81.

held in the tube, being retained by the atmospheric pressure, and if the tube be placed over a tumbler, and the thumb be raised, the wine will flow out. This is the principle of the dropping tube, employed by druggists and others.

Pressure on the Human Body.

119. The pressure on each square inch of the body is 15 lbs.; hence, on the whole body the pressure is enormous. If we take the surface of the human body equal to 2000 square inches, which is not far from the average in the case of an adult, the pressure amounts to 30,000 pounds, or 15 tons.

If it be asked why the body is not crushed by this enormous pressure, the answer is, because it is uniformly distributed over the whole surface, and is resisted by the elastic force of air, and other gases, distributed through the tissues of the body.

The following experiment shows that the tissues of the human

Describe it and its use. What is the dropping tube? (**119.**) What is the amount of atmospheric pressure on the human body? How is this pressure resisted?

body contain air and gases, whose elasticity resists the atmospheric pressure. Let the hand be pressed closely upon the mouth of a glass cylinder, whose interior communicates with the air-pump, as shown in Fig. 82. No inconvenience will be felt. But if the air be exhausted from the cylinder, the flesh of the hand will be forced into the cylinder by the pressure from without, which is no longer resisted by the pressure of the air. The hand swells, and the blood tends to flow out through the pores.

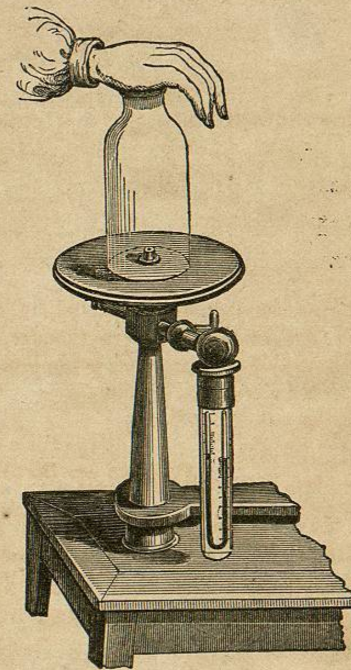

Fig. 82.

The question may be asked, why, when the hand is placed upon a body, it is not retained there by the pressure of the atmosphere. The answer is, there is a thin layer of air between the hand and the body, which exactly counterbalances the effect of the external pressure. Were the air perfectly excluded from between the hand and the body, there would be a strong tendency to adherence between them.

The operation of cupping, in medicine, depends upon the principle just explained.

How shown that the tissues of the body contain gases? Explain experiment. Principle of cupping.

II.—MEASURE OF THE ELASTIC FORCE OF GASES.

Mariotte's Law.

120. When a given mass of any gas or vapor is compressed, so as to occupy a smaller space, its elastic force is increased; on the contrary, when the volume is increased, its elastic force is diminished.

The law of increase and diminution of elastic force was first made known by MARIOTTE; hence it was called by his name. MARIOTTE's law may be enunciated as follows:

The elastic force of any given amount of gas, whose temperature remains the same, varies inversely as its volume.

As a consequence of this law it follows that,

If the temperature remains constant, the elastic force varies as the density.

Mariotte's Tube.

121. MARIOTTE's law may be verified by means of an apparatus, shown in Figs. 83 and 84, called *Mariotte's Tube.* This tube is of glass, bent into the shape of a letter J. The short branch is closed, and the long one open at the top. The tube is attached to a wooden frame, provided with suitable scales for measuring the heights of mercury and air in the two branches.

The instrument having been placed vertical, a sufficient quantity of mercury is poured into the long branch to cut off communication between the two branches, as shown in Fig. 83. The level of the mercury in the two branches is the same, and this level is at the 0 point of the two scales. The air in the short branch is of the same density, and has the same tension as that of the external atmosphere.

(**120.**) What is MARIOTTE's Law? Consequence? (**121.**) Describe Mariotte's Tube.

If an additional quantity of mercury be poured into the longer branch of the tube, it will press upon the air in the shorter branch, and compress it. If the difference of level

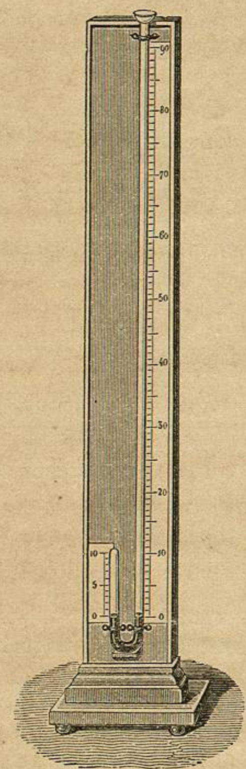

Fig. 83.

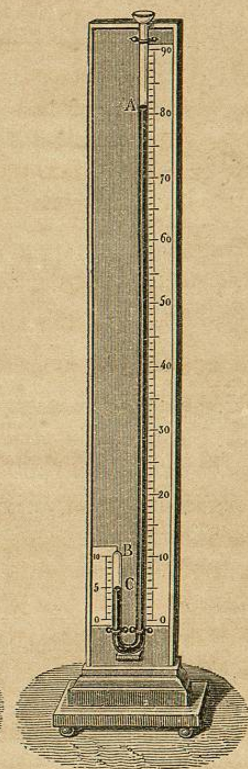

Fig. 84.

in the two branches be made equal to the height of the barometrical column, as shown in Fig. 84 (where the difference is 76 centimetres, or 29.92 inches), the air will be compressed into BC, one half of its original bulk.

How used to verify the law?

In the figure, the air in *BC* is subjected to the pressure of two atmospheres, one from the actual atmosphere, transmitted through the mercury, and an equal pressure from the weight of the mercury, *AC*, which is equal to that of an atmosphere.

If the difference of height, *AC*, be made equal to two, three, four, &c., times that of the barometric column, the air in *BC* will be reduced to one third, one fourth, one fifth, &c., of its original bulk.

Manometers.

122. A MANOMETER is an apparatus for measuring the elastic force of a gas or vapor.

There are two principal kinds of manometers, the *open* and the *closed* manometer.

The Open Manometer.

123. Fig. 85 represents an OPEN MANOMETER, such as is often used for measuring the pressure of steam in a boiler.

It consists of a narrow tube of glass fixed against a vertical wall, and communicating with a cistern of mercury, *C*. A pipe leads from the boiler to the cistern, *C*, and by means of a stop-cock, steam may be admitted to the cistern, or cut off at pleasure.

When the tension of the steam in the boiler is just equal to that of the atmosphere, the mercury stands at the same level in the tube and cistern. When the tension of the steam becomes equal to twice that of the atmosphere, the mercury is forced from the cistern into the pipe, where it rises till the difference of level is 30 inches. This is marked 2 on the tube, and when the mercury is at this division, the tension of the steam is two atmospheres. The divisions 3, 4, 5, &c., are placed at distances of 30 inches, and when the mercury stands at any one of them, the manometer indicates a tension of the corresponding number of atmospheres.

(**122.**) What is a Manometer? How many kinds are employed? What are they?
(**123.**) Describe the Open Manometer. *Explain its action.*

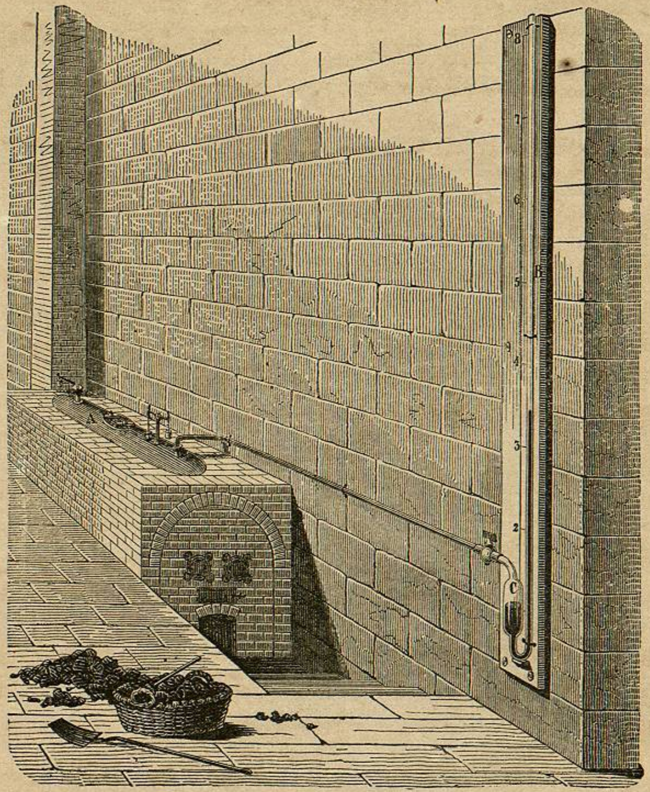

Fig. 85.

In the figure, the tension indicated is $3\frac{1}{2}$ atmospheres.

The Closed Manometer.

124. The CLOSED MANOMETER is shown in Fig. 86, and differs from the one just described, in having its vertical tube closed at the top. It is graduated on the principle enunciated in MARIOTTE's law.

(**124.**) Describe the Closed Manometer. How is it graduated?

When the pressure in the boiler is one atmosphere, the mercury in the cistern and tube are at the same level, the tension of the steam and the elastic force of the air just balancing each other. When the pressure becomes two, three, four, &c., atmospheres, the air in the closed tube will occupy one half, one third, one fourth, &c., the space it did before, allowance being made for the weight of the mercury which is forced up into the tube. The instrument having been graduated, its use is evident. When it is desired to ascertain the tension of the steam in the boiler, the cock is turned, and the height to which the mercury ascends in the tube, indicates the tension in atmospheres. Any number of subdivisions may be made in either of the two manometers described.

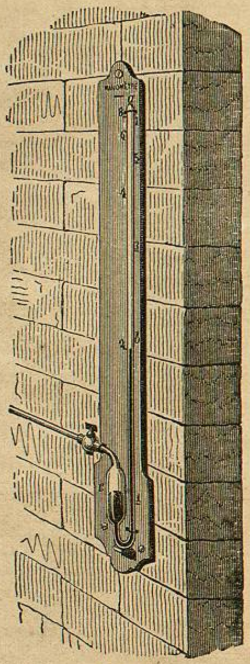

Fig. 86.

Besides these, there is a metallic manometer, invented by M. Bourdon, and known as Bourdon's Metallic Manometer. It is not so reliable as those described.

III.—APPLICATION TO PUMPS AND OTHER MACHINES.

The Air-pump.

125. An Air-pump is a machine for exhausting the air from a closed space. The air-pump was invented by Otto de Guéricke, in 1650.

A perspective view of one of the most common forms of the air-pump is given in Fig. 87. The details of its construction will be best studied from Figs. 88 and 89; the former represents a longi-

Illustrate. How is this manometer used? (**125.**) What is an Air-pump? When invented, and by whom?

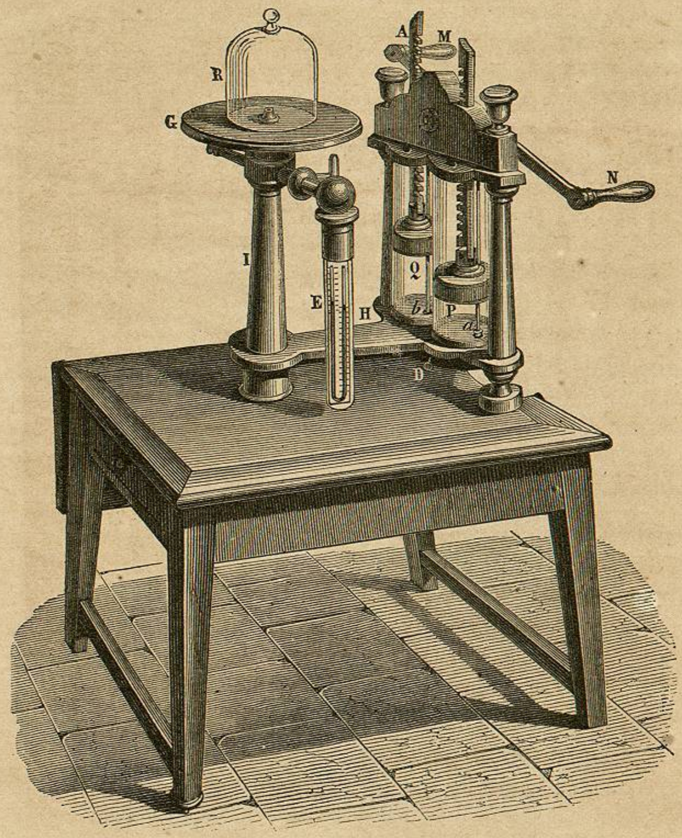

Fig. 87.

tudinal, and the latter a transverse section. In all of the figures, the same letters indicate corresponding parts.

The air-pump consists of two glass cylinders, called *barrels*, in which are pistons, *P* and *Q*, made of leather, thoroughly soaked in oil. The pistons are attached to rods, and are elevated and depressed by a lever, *NM*, Fig. 89, which imparts an oscillating motion to a pinion, *K*. The teeth of this pinion engage with corresponding ones

Give a complete description of the air-pump. Barrels. Pistons Rods.