some of the water to enter. The air in D is at first condensed by the pressure of the water thus admitted; but, immediately expanding by reason of its elasticity, it drives the water into F, for the closing of the valve prevents it from returning to B. By this time the water in B is again at rest, the valve E opens, and the whole process is repeated.

By successive impulses the water may be raised in F to a great height. A descent of four or five feet from the reservoir is sufficient. Care must be taken to have the valve E just heavy enough to fall when B is at rest, and not so heavy as to prevent it from readily rising as the momentum of the stream increases. The pipe B must also be of such length that the water, when arrested in its course, may not be thrown back on the reservoir.

387. Hydraulic Rams afford a cheap and convenient means of raising water in small quantities to great heights, wherever there is a spring or brook having a slight elevation. They are used for a variety of purposes, and particularly when a supply of water is needed for agricultural operations.

EXAMPLES FOR PRACTICE.

☞ *Friction is left out of account in these examples.*

1. (*See* § 356, *rule in italics.*) Two streams issue from different orifices in the same vessel with velocities that are to each other as 1 to 6. How many times farther from the surface is the one than the other?
2. The stream A runs from an orifice in a vessel three times as fast as the stream B. How do their distances below the surface of the liquid compare?
3. In a vat full of beer there are two orifices of equal size; one 9 inches below the surface, and the other 25. How does the velocity of the latter compare with that of the former?
4. There are three apertures in a reservoir of water, 1, 4, and 16 feet below the surface. With what comparative velocity will their streams flow?
5. A stream flows from an aperture in a vessel at the rate of 4 feet in a second. I wish to have another stream from the same vessel with a velocity of 16 feet per second. How much farther below the surface than the first must it be?
6. (*See* § 359.) A vat full of ale, 3 feet high, has four apertures in it, 3, 12, 18, and 24 inches respectively from the top. Through which will the liquid spout to the greatest horizontal distance? Which next? Which next?
7. (*See* § 360.) How much water will be discharged every minute from an orifice of 3 square inches, the stream flowing at the rate of 5 feet in a second, and the vessel being kept replenished?

Its mode of operating. How great a descent is required? What precautions are necessary? 387. In what case may hydraulic rams be used with advantage?

How much will be discharged every minute from another orifice in the same vessel, equally large, but situated four times as far below the surface of the liquid?

8. A stream flows from a hole in the bottom of a vessel with a velocity of 6 feet in a second. The hole has an area of 5 square inches, and the vessel is emptied in 15 seconds. How much water does the vessel hold?
9. (*See* § 376.) A stream having a momentum equivalent to 100 units of work is applied to an Undershot Wheel; how many units of work will it perform?—*Ans.* 25.

(*See* § 377.) How many units of work will it perform, if applied to an Overshot Wheel?

(*See* § 378.) How many, if applied to a Breast-wheel?

(*See* § 379.) How many, if applied to a Turbine?

CHAPTER XII.

PNEUMATICS.

388. Pneumatics is the science that treats of air and the other elastic fluids, their properties, and the machines in which they are applied.

389. Division of Elastic Fluids.—The elastic fluids are divided into two classes:—

I. Gases, or such as retain their elastic form under ordinary circumstances. Some of the gases, under a high degree of pressure, assume a liquid form; as, carbonic acid and chlorine; others, such as oxygen and nitrogen, can not be converted into liquids by any known process.

II. Vapors, or elastic fluids produced by heat from liquids and solids. When cooled down, they resume the liquid or solid form. Steam, the vapor of water, is an example.

390. All gases and vapors have the same properties.

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388. What is Pneumatics? 389. Into what two classes are elastic fluids divided? What are gases? What difference is there in the gases? What are vapors? 390. In

The principles of Pneumatics, therefore, relate to all alike, though they are most frequently exhibited and applied in the case of air, with which we have far more to do than with any other elastic fluid.

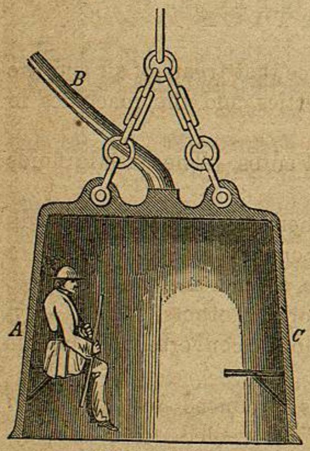
Air.

391. Air is the elastic fluid that we breathe. It surrounds the earth to a distance of about fifty miles from its surface, and forms what is called the Atmosphere. It exists in every substance, entering the minutest pores.

392. Vacuums.—Air may be removed from a vessel with an instrument called the Air-pump. A Vacuum is then said to be produced. Vacuums sometimes result from natural causes; but they last only for an instant, as the surrounding air at once rushes in to fill them. Hence the old philosophers used to say, *Nature abhors a vacuum.*

393. Properties of Air.—Air can not be seen, but it can be felt by moving the hand rapidly through it. It is therefore material, and has all the essential properties of matter.

Fig. 175.



THE DIVING-BELL.

394. Air is impenetrable.

395. *The Diving-bell.*—The impenetrability of air is shown by the Diving-bell, represented in Fig. 175. A C is a large iron vessel, shaped somewhat like an inverted tumbler, and attached to a chain, by which it is let down in the water. As the vessel descends, the air in it is condensed by the upward pressure of the liquid, and water enters. The lower it gets, the more the air is compressed, and the greater the amount of water admitted. The impenetrability of the air, however, keeps the greater part of the bell

what are the principles of Pneumatics most frequently exhibited, and why? 391. What is Air? How far does it extend from the earth's surface? What does it constitute? 392. What is a Vacuum? What did the old philosophers say, and why? 393. What proves the air to be material? 394. What apparatus shows the impenetrability of air? 395. Describe the Diving-bell. Explain how descents are made with

clear of water, so that several persons may descend in it to the bottom of the sea.

As fast as the air is vitiated by the breath, it is let off by a stop-cock, while fresh air is supplied from above by a condensing syringe, through the pipe B. Air may be thus forced down in sufficient quantities to expel the water altogether from the bell, so that the divers can move about without difficulty on the bottom of the sea. If air were not impenetrable, the bell would be filled with water, and the divers drowned.

When the diving-bell was invented, is not known. History makes no mention of it before the sixteenth century. At that time, we are told, two Greeks, in the presence of the emperor Charles V. and several thousand spectators, let themselves down under water, at Toledo in Spain, in a large inverted kettle, and rose again without being wet. In 1665, a kind of bell was employed off the Hebrides, for the purpose of recovering the treasure lost in several ships belonging to the Invincible Armada. From that time to the present, various improvements have been made in the diving-bell; and it is now extensively used for clearing out harbors, laying the foundation of submarine walls, and recovering articles lost by shipwreck.

396. Air is compressible.

This is proved with the diving-bell. If the air were not compressible, no water would enter the bell as it descended.

397. Air is elastic.

This also may be shown with the diving-bell. When, on its descent, water has entered, on account of the air's being compressed, let the bell be raised, and the air will resume its original bulk, expelling the water.

Fig. 176.


BOTTLE IMPS.

Bottle Imps.—The compressibility and elasticity of air may be exhibited in an amusing way with the apparatus represented in Fig. 176. In a vessel nearly full of water are placed several small balloons, or hollow figures of men, &c., made of colored glass, and called Bottle Imps. Each figure has a little hole in the bottom, and is of such specific gravity that it will just float in water. A piece of thin india rubber is tied over the mouth of the vessel, so as to cut off communication with the external air. Now press on the india rubber cover. The water at once transmits the pressure to the air in the hollow figures. This air is condensed, water enters, the specific gravity of the figures is increased,

it. What is the first mention made of the diving-bell in history? In 1665, for what purpose was it used? For what is it now extensively used? 396. How does the diving-bell prove air to be compressible? 397. How does it prove air to be elastic? What properties in air do the Bottle Imps illustrate? Describe the bottle imps, and

and they descend. On removing the fingers from the cover, the air, by reason of its elasticity, resumes its original bulk, and the figures rise. By thus playing on the india rubber, the figures may be made to dance up and down.

398. *Mariotte's Law.*—The elastic fluids are the most easily compressed of all substances. *The greater the pressure to which they are subjected, the less space they occupy, and the greater their density.* A body of air which under a certain pressure occupies a cubic foot, under twice that pressure will be condensed into half a cubic foot; under three times that pressure, into one-third of a cubic foot, &c. This principle, variously stated, is called, from its discoverer, Mariotte's Law.

The more the elastic fluids are compressed, the greater is their resistance to the pressure. Hence, their elastic force increases with their density.

399. *The Air-gun.*—By subjecting a body of air to a great pressure, we may increase its elastic force sufficiently to produce wonderful effects. The Air-gun is an example. It consists of a strong metallic vessel, into which air is forced till it is in a state of high condensation. The vessel is then attached to a barrel like that of an ordinary gun, to the bottom of which a bullet is fitted. Pulling a trigger opens a valve, the condensed air rushes forth, and drives the bullet out with great force.

One supply of condensed air is sufficient for several discharges, though each is weaker than the preceding one. The labor required for condensing the air prevents this instrument from being much used; but as it makes less noise, when discharged, than the ordinary gun, it is sometimes employed by assassins.

400. Air has weight.

Weigh a flask full of air, and then weigh the same flask with the air exhausted. The difference indicates the weight of the air contained.

401. Experiments show the weight of 100 cubic inches of air to be about $30\frac{1}{2}$ grains. This makes it 828 times lighter than water. It has been computed that the weight of the whole atmosphere surrounding the earth is equal to that of a globe of lead 60 miles in diameter.

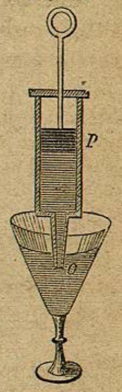
explain the principle on which they dance up and down. 398. What substances are the most easily compressed? What is Mariotte's Law? To what is the elastic force of gases and vapors proportioned? 399. How may a body of air be made to produce wonderful effects? What instrument proves this? Describe the Air-gun, and its operation. Why is not the air-gun used more? By whom is it sometimes employed? 400. Prove that air has weight. 401. What is the weight of 100 cubic inches of air?

Atmospheric Pressure.

402. The particles of air, like those of the other elastic fluids, mutually repel each other. The atmosphere would therefore spread out into space, and become exceedingly rare, if it were not for the attraction of the earth. This prevents it from extending more than fifty miles from the surface, and gives it weight.

403. Since air has weight, it exerts a pressure on all terrestrial bodies. This is known as Atmospheric Pressure. The pressure on any given body is equal to the weight of the column of air resting upon it, and therefore varies according to its size.

Fig. 177.



404. Experiments.—The pressure of the atmosphere is proved by experiments.

Experiment 1.—Take a common syringe, represented in Fig. 177, and let the piston, P, rest on the bottom of the barrel. Insert the nozzle, O, in a vessel of water, and raise the piston. The water enters through O, and follows the piston, as shown in the Figure.

What causes the water to rise? The piston, being air-tight, as it is drawn up, leaves a vacuum behind it; and the pressure of the atmosphere on the water in the vessel drives it into the barrel through O. If the piston does not fit the barrel tightly enough to exclude the air above, no water enters, because the pressure of the air from without is then counterbalanced by that from within the barrel.

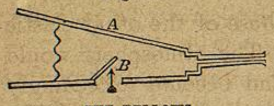
Fig. 178.

Exp. 2.—Take a small tube, close one end with the finger, fill it with water, and carefully invert it, as shown in Fig. 178. The water is kept in the tube by atmospheric pressure. Remove the finger, and the downward pressure of the atmosphere, which was before cut off, will counterbalance the upward pressure, and the water will fall by its own weight.

Exp. 3.—Fill a wine-glass with water, and cover the mouth with a piece of stiff paper. Place the hand over the paper, and invert the glass. On carefully removing

What is the weight of the whole atmosphere? 402. What prevents the atmosphere from spreading out into space? 403. What is Atmospheric Pressure? What causes atmospheric pressure? To what is the atmospheric pressure on any given body equal? 404. Describe the experiment with the syringe that proves the pressure of the atmosphere. What will prevent the water from rising in the syringe? Describe the hand, the water will be found to remain in the glass, supported there by atmospheric pressure.

Fig. 179.

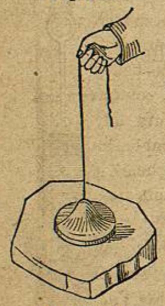


THE BELLOWS.

Exp. 4.—When we raise the top board, A, of a common bellows (see Fig. 179), the valve B in the lower board opens. This is because a vacuum is formed within the bellows, and the atmospheric pressure forces the valve up and drives in a portion of the external air.

The same principle is involved in the act of breathing. The cells in the lungs are expanded by muscular action, a vacuum is thus formed, and the pressure of the atmosphere drives in the outer air through the nose or mouth. In a few seconds the muscles contract, and the same air, laden with impurities received from the blood in the lungs, is expelled.

Fig. 180.



THE SUCKER.

405. The Sucker, a play-thing used by boys, shows the force of atmospheric pressure. It consists of a circular piece of leather with a string attached to the middle. The leather, being first wet so that it may adapt itself to the surface, is pressed firmly upon a flat stone. The string is then gently pulled, so as to form a vacuum between the leather and the stone. On this, the atmospheric pressure from above, not being counterbalanced from beneath, acts on the leather with such force that a stone of great weight may be lifted without the sucker's becoming detached. If a hole is made in the leather, air rushes in, the pressure from above is counterbalanced, and the stone falls by its own weight.

When flies walk on a ceiling, their feet act like suckers. Vacuums are formed beneath them, and they are sustained by atmospheric pressure. It is in the same way that the shell-fish called limpets fasten themselves to rocks.

406. Supported by the pressure of the atmosphere below, while it is cut off from that above, a liquid will not flow from the tap of a barrel unless a small opening is made in the top. As soon as this is done, air is admitted,

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the experiment with a small tube that proves the pressure of the atmosphere. How may water be supported in a wine-glass by atmospheric pressure? How is the pressure of the atmosphere exhibited with a common bellows? How do we breathe? 405. Explain the principle involved in the Sucker. How are flies able to walk on a ceiling? 406. Why, when a barrel is tapped, must a hole be made in the top?

the upward pressure is counterbalanced, and the liquid flows continuously. On the same principle, a small hole is made in the lid of a tea-pot.

407. THE BAROMETER.—The pressure of the atmosphere differs at different times and different places. To measure it, an instrument called the Barometer is used.

The barometer was invented about the middle of the seventeenth century. It was the result of a celebrated experiment performed by Torricelli [*to-re-chel'-le*], the friend and pupil of Galileo.

408. *Torricellian Experiment.*—The Duke of Tuscany, having dug a well of great depth, and tried to raise water from it with an ordinary pump, found to his surprise that the water would not rise more than 32 feet. Galileo, to whom the fact was referred, was unable to explain it; but shortly before his death he requested Torricelli to investigate the subject. Torricelli, suspecting that the water was raised and supported by atmospheric pressure, proceeded to test the truth of his opinion by experimenting with a column of mercury. Mercury is nearly 14 times as heavy as water; if, therefore, atmospheric pressure supported a column of water 32 feet high, it would support a column of mercury only about one-fourteenth of that height, or 28 inches. Accordingly, he procured a tube 3 feet long, sealed at one end; and having filled it with mercury, and stopped the open end with his finger, he inverted the tube in a vessel of mercury, as shown in Fig. 181. When he removed his finger, the mercury fell, and finally settled, as he had supposed it would, at a height of about 28 inches, leaving a vacuum in the upper part of the tube. This is the famous Torricellian Vacuum.

Fig. 181.

Torricelli did not live to follow up his discovery; but the French philosopher, Pascal, succeeded him with a variety of ingenious experiments. It occurred to Pascal that, if the columns of water and mercury were supported by the pressure of the atmosphere, then at great elevations, where this pressure would necessarily be less, the height of the columns supported would also be less. He tried the experiment on a mountain in Auvergne [*o-vārn'*]. At the foot of the mountain, the mercury stood at 28 inches; at the top, it was below 25; and at intervening distances it stood between the two. This proved beyond doubt that the atmosphere exerted a pressure, and that this pressure varied according to the distance above the level of the sea. Perceiving how valuable such an instrument would be for

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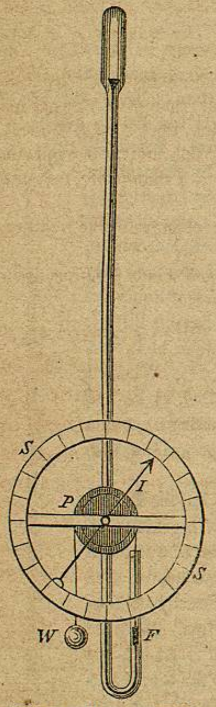
407. What is the Barometer? When was it invented? Of what was it the result? 408. Relate the circumstances that first directed attention to the subject. Give an account of Torricelli's experiment. What is meant by the Torricellian Vacuum? Who followed up Torricelli's discovery? Give an account of Pascal's experiment.

measuring heights, Pascal soon constructed a Barometer, consisting of a tube and vessel of mercury so attached as to be conveniently carried.

409. *Kinds of Barometers.*—There are several kinds of barometers. The simplest consists of Torricelli's tube and vessel of mercury, with a graduated scale attached to the upper part. The mercury never rises above 31 inches, and seldom falls below 27. The scale is therefore applied only to that part of the tube which lies between these limits.

Fig. 182.



THE WHEEL BAROMETER.

The Wheel Barometer is exhibited in Fig. 182.

Here the tube, instead of resting in a vessel of mercury, is bent upward at its lower extremity. A float, F, is supported by the mercury in the short arm of the tube. To this float is attached a thread, which passes over the pulley P, and is attached to the ball W. When the mercury falls in the long arm of the tube, it must rise in the short arm, and with it rises the float F. The thread turns the pulley P, and this moves the index I, which is so arranged as to traverse the graduated scale S S.

410. *The Barometer as a Weather-guide.*—The barometer shows that the pressure of the atmosphere at any given place is different at different times. This is because the air is constantly varying in density, on account of a greater or less intermixture of foreign substances. When the air is densest, the mercury stands highest, and we generally have clear weather; but, when the air is rarefied, the mercury falls, and rain not unfrequently follows. Hence, the barometer has been used for predicting changes of weather; and the words FAIR, CHANGE, RAIN, are placed at different points on the scale, to indicate the weather which may be expected when the mercury reaches either of those levels.

What did it prove? 409. Of what does the simplest kind of barometer consist? To what part of the tube is the scale confined, and why? Describe the Wheel Barometer, and its mode of operation. 410. What does the barometer show with respect to the pressure of the atmosphere? What occasions this difference? When the air is densest, what generally follows? When it is rarefied, what follows? In view of this,

411. The only reliable indications, however, afforded by the barometer are *changes* in the level of the mercury. No regard should be paid to the particular point at which it stands at any given time; we should merely ask, is it rising or falling? The following rules generally hold good:—

1. After much dry weather, if the mercury falls steadily, rain will ensue, though it may not begin for several days. The longer it is in coming, the longer it will last.
2. After much wet weather, if the mercury, standing below its medium height, rises steadily, fine weather will ensue, though it may not begin for several days. The longer it is in coming, the longer it will last.
3. A sudden fall of the barometer, in spring or fall, indicates wind; in very hot weather, a thunder-storm; in winter, a change of wind, and rain or snow according to the temperature.
4. Sudden changes of the mercury indicate violent changes of the weather, but not permanent ones.
5. A rise of mercury in autumn, after much wet and windy weather, indicates the approach of cold.

412. At sea, the barometer may be relied on with tolerable certainty, and it is therefore exceedingly useful to navigators. Violent and frequent changes in the mercury almost invariably precede a sudden storm. Warned in time, the prudent mariner furls his sails, and thus escapes the fury of the hurricane which would have proved fatal to his craft had it struck her unprepared.

Dr. Arnott gives the following account of his preservation at sea through the warning of the barometer:—"It was in a southern latitude; the sun had just set with placid appearance, closing a beautiful afternoon; and the usual mirth of the evening watch was proceeding, when the captain's order came to prepare with all haste for a storm: the barometer had begun to fall with appalling rapidity. As yet the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparation; but the required preparations were not completed, when a more awful hurricane burst upon them than the most experienced had ever braved.

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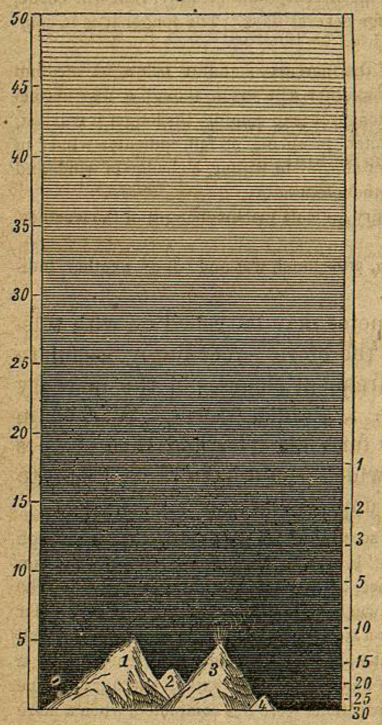
to what use has the barometer been applied? 411. What are the only reliable indications afforded by the barometer? What does a steady fall of mercury in the barometer after much dry weather indicate? What does a rise of mercury after much wet weather indicate? What does a sudden fall indicate at the different seasons? What do sudden changes indicate? What does a rise of mercury in autumn indicate? 412. What is said of the barometer at sea? Relate the circumstances of Dr. Arnott's

Nothing could withstand it; the sails, already furled and closely bound to the yards, were riven away in tatters; even the bare yards and masts were in great part disabled, and at one time the whole rigging had nearly fallen by the board. In that awful night, but for the little tube of mercury which had given the warning, neither the strength of the noble ship nor the skill and energies of the commander could have saved one man to tell the tale."

413. Density of the Air at different Levels.—The lowest parts of the atmosphere are the densest, as they have the greatest quantity of air pressing on them from above.

Fig. 183.



1. *Highest Peak of the Himalayas.*
2. *Highest Peak of the Alps.*
3. *Highest Peak of the Andes.*
4. *Mount Mitchell, N. Carolina.*

414. At the level of the sea, the pressure of the atmosphere on every square inch of surface is 15 pounds. The body of a man of ordinary size has a surface of about 2,000 square inches, and is therefore subjected to the enormous pressure of 30,000 pounds. We do not feel this pressure, because it is counterbalanced by that of the air within our bodies.

415. The higher we go above the level of the sea, the less is the pressure of the atmosphere and the rarer the air. At an elevation of 18 miles, the mercury would fall to 1 inch, — that is, the air above that point is so rare,

preservation at sea by means of the barometer. 413. What parts of the atmosphere are densest, and why? 414. How great is the pressure of the atmosphere at the level of the sea? How great is the pressure on the body of a man of ordinary size? Why

that a column of it 30 miles high weighs no more than an equal column of mercury 1 inch in height.

The shading in Fig. 183 shows the gradual increase in the density of the air as the surface of the earth is approached. The figures in the left margin represent the height of the atmosphere in miles; those on the right, the corresponding height, in inches, at which the mercury stands in the barometer. On the top of Mount Mitchell and Mount Washington, the most elevated peaks in the United States east of the Mississippi, somewhat over a mile high, it stands at 24 inches; on the highest peaks of the Himalayas and Andes, which are about five miles high, at no more than 12.

416. The rarity of the air is painfully felt by those who ascend to great heights on mountains. The pressure of the external air being diminished, that which is in the body expands, the delicate blood-vessels burst, the skin cracks, and blood issues from the nose and ears. Among the Andes, the Indians are subject to a malady called *veta*, which is caused by the rarity of the air. The head aches violently, its veins are swollen, the extremities grow cold, and breathing becomes difficult.

Effect of Heat on Air.

417. Air is rarefied by heat.

Throw some burning paper into a wine-glass, and before the flame goes out place your hand over the top. The glass will be found to adhere to your hand. This is because the heat rarefies the air within, and thus expels most of it before the top is covered. The pressure of the external air, not being counterbalanced by any pressure from within, fastens the glass and hand together.

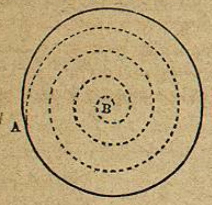
418. Cupping-glasses are made to draw on this principle. Incisions having been made in the skin, the sides of the glass are moistened with alcohol, and flame is applied. While the alcohol is burning, the glass is inverted on the skin. The pressure of the air in the body, no longer counterbalanced by the external pressure, causes a flow of blood into the cup.

419. Heated air, being lighter than that which surrounds

do we not feel this pressure? 415. What is said of the air, as we ascend above the sea-level? How would the mercury stand at a height of 18 miles? What does Fig. 183 show? How does the mercury in the barometer stand on the top of Mount Mitchell? On the tops of the Himalayas? 416. What sensations are experienced by persons who ascend to great heights on mountains? Describe the symptoms of the *veta*. 417. What is the effect of heat on air? How may the rarefaction of air by heat be shown? 418. Explain the operation of cupping-glasses. 419. Why does it, ascends till it reaches a region of the atmosphere as rare as itself.

This is the reason why smoke rises. So, when a fire is kindled in a grate, a draft is produced in the chimney. The air near the fire is rarefied and ascends. A vacuum is thus formed for the instant; cold air rushes in to fill it; this in turn is heated and rises, and thus there is a constant passage of hot air up through the chimney.

Fig. 184.



To show the ascent of hot air, take a circular piece of paper, as represented in Fig. 184, and, commencing at any point of the outer edge, as A, cut in the direction of the dotted line. Support it from beneath at B on a piece of wire, and it will hang down, resembling in shape the threads of a cork-screw. If the paper thus suspended be held over a hot stove, it will be carried rapidly round by the ascending currents of heated air.

420. Balloons.—By observing the rise of smoke, Stephen and Joseph Montgolfier [*mon-gol-fe-ā'*], paper-manufacturers in France, were led in 1782 to the invention of balloons. The following year, they exhibited their invention to the public.

An immense bag of linen lined with paper was prepared, and brought directly over a fire of chopped straw. In a few minutes, the balloon was filled with rarefied air and released from its fastenings. It rose about a mile, remained suspended ten minutes, and reached the ground a mile and a half from the place of its ascent. The same year, two persons ascended to a height of 3,000 feet in the basket of a smoke balloon, and came down in safety.

On the 1st of January, 1784, a successful ascent was made in a balloon inflated with hydrogen. This gas is now generally used for the purpose, on account of its superior buoyancy. Even when badly prepared, it has but one-sixth of the weight of air, and is three times as light as Montgolfier's mixture of heated air and smoke.

421. Balloons have not as yet been turned to any practical use, from the fact that they are completely at the mercy of the wind, no way of steering them having been devised. A theory has lately been put forth, however, that at a certain height of the atmosphere currents are always setting from

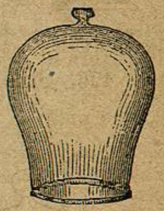
heated air rise? Explain how the kindling of a fire causes a draft in a chimney. How may the ascent of hot air be shown? 420. By whom and when were balloons invented? Describe the Montgolfiers' balloon, and its ascent. When was the first successful ascent made in a balloon inflated with hydrogen? Why is hydrogen now used for

west to east; if this be so, aërial voyages may be made with tolerable certainty, at least in one direction. The theory in question has been in part confirmed by a balloon voyage (the most remarkable on record) made July 1, 1859. Four persons started from St. Louis, and in 19 hours, 40 minutes, landed in Jefferson Co., N. Y., near Lake Ontario,—having travelled about 1,000 miles, at a rate exceeding that of the fastest railroad train.

422. Long before the invention of balloons, attempts were made to navigate the air. At different periods not long after the Christian era, adventurous men launched themselves from the tops of high buildings, and with different sorts of apparatus which they had prepared moved a short distance through the air. Mechanical contrivances resembling wings were more than once resorted to; but several who tried them met with serious accidents, and it was at last proved that wings sufficiently large to support a man in the air would be too heavy for him to move.

The Air-pump.

Fig. 185.



A RECEIVER.

423. The Air-pump is an instrument used for removing the air from a vessel called a Receiver. Receivers are made of glass, and are usually of the shape represented in Fig. 185.

424. Invention of the Air-pump.—The air-pump was invented 1654 A. D., by Otto Guericke [*gā'-re-kā*], burgomaster of Magdeburg, Germany.

Guericke's first attempt to obtain a vacuum was made with a barrel full of water. Having closed it tightly, he applied a pump to the lower part and commenced drawing off the water. Could he have done this and kept the air out, a vacuum would have been formed; but he had not proceeded far, when the air from without began to force its way with a loud noise through the seams of the barrel. To remedy the difficulty, Guericke substituted a metallic globe for his barrel of water, and the experiment was then successful.

inflating balloons? 421. Why have not balloons been turned to practical use? What remarkable voyage has lately been made? 422. Give an account of the early attempts to navigate the air. 423. What is the Air-pump? Of what are receivers made? 424. By whom and when was the air-pump invented? Give an account of Guericke's first attempt to obtain a vacuum. How did he finally succeed? Describe Gue-