on the inner sides of the piston rods, *A* and *B*. The machine is so arranged that one rod ascends whilst the other descends. The cylinders rest upon and are firmly attached to a platform, *H*, Fig. 88. On the same platform, *H*, is a column, *I*, which supports a plate, *G*. Resting upon the plate *G*, is a bell glass, *R*, called a *receiver*. The receiver communicates with both cylinders by a pipe, shown in Fig. 88.

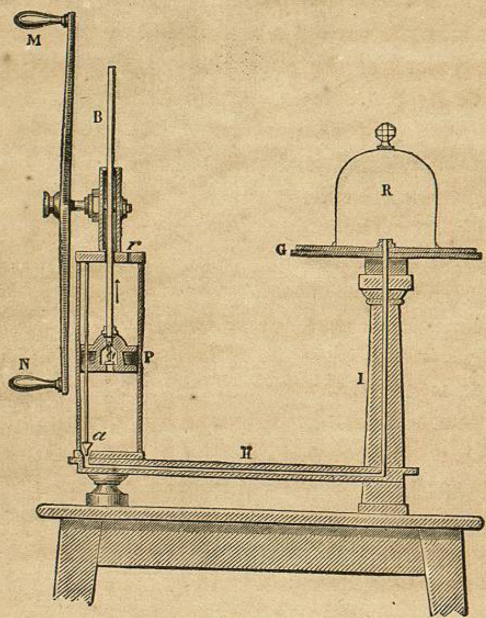

Fig. 88.

This pipe branches near the cylinders, one branch leading to each cylinder, as shown in Fig. 89. The pipe communicates with the cylinders by openings, which may be closed by conical valves, *a* and *b*. The valves *a* and *b* are attached to rods which pass through the pistons, and fitted to slide with gentle friction as the pistons move up and down. In the pistons are valves, *s* and *t*, which are gently

Receiver. Pipe. Valves. Valve rods.

pressed by spiral springs so as to permit the condensed air to escape and then to close the orifices in the valves. All of the valves, *a*, *b*, *s*, and *t*, open upwards.

In explaining the action of the air-pump, it will be sufficient to consider a single barrel, as shown in Fig. 88. The piston, *P*, being at the bottom of the barrel, the valves *a* and *t* are closed. If the piston be raised, the valve *a* is opened, whilst the valve *t* is kept closed by the spiral spring and the pressure of the atmosphere. The valve *a* is soon arrested by its rod coming in contact with the top of the barrel, and it then remains open during the ascent of *P*. The air in the barrel above the piston is driven out at the opening, *r*, and that in the receiver and pipe expands so as to fill the receiver, pipe, and barrel. If the piston, *P*, be depressed, it at once closes the valve *a*, and compresses the air in the barrel till its elastic force becomes great enough to force open the valve *t*, when it escapes into the atmosphere.

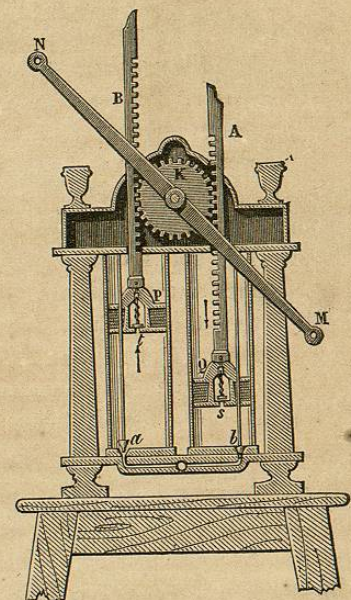

Fig. 89.

By this double stroke of the piston, *P*, a portion of the air is exhausted from the receiver, and if a second double stroke be made, a portion of what remains may in like manner be exhausted, and so on until nearly a perfect vacuum is formed in the receiver,

Describe the action of the air-pump in detail.

R, or in any other closed vessel attached to the pipe of the machine.

What has been said of one barrel, is equally true of the other; in fact, the instrument, as figured, is a double pump.

Measure of the Rarefaction produced.

126. In order to measure the degree of rarefaction produced, a glass cylinder, *E*, Fig. 87, is connected with the pipe by means of an opening through the column *I*. In this cylinder, is a glass tube bent into the form of the letter U, one branch being closed at the top, and the other open. The tube has its closed branch filled with mercury, and is called a *siphon gauge*.

The mercury, under ordinary circumstances, is kept in the closed branch by the atmospheric pressure, but as the air becomes rarefied in the receiver, the tension of the air becomes less and less, and finally the mercury falls in the closed branch and rises in the open one. The difference of level between the mercury in the two branches, is due to the tension of the rarefied air, and if this difference be determined by means of a proper scale attached to the gauge, the tension can be found. Thus, if the difference of level is reduced to one inch, the tension of the air in the receiver will be only one thirtieth part of the tension of the external atmosphere.

Experiments with the Air-pump.

127. We have already described several experiments requiring the employment of the air-pump, such as the shower of mercury, Fig. 1; the fall of bodies in a vacuum, Fig. 2; the bladder in a vacuum, Fig. 70; the bursting membrane, Fig. 72; and finally, the hemispheres of Magdebourg, Fig. 73.

(**126.**) How may the degree of rarefaction be measured? What is the siphon gauge? Explain its action and use.

The machine may be used to show that the air is necessary to the support of combustion and animal life. If a lighted taper be placed under the receiver, and the air exhausted, the light will grow dim, and finally will go out entirely. If an animal or bird be placed under the receiver, and the air exhausted, it will struggle and soon die. This experiment is shown in Fig. 90.

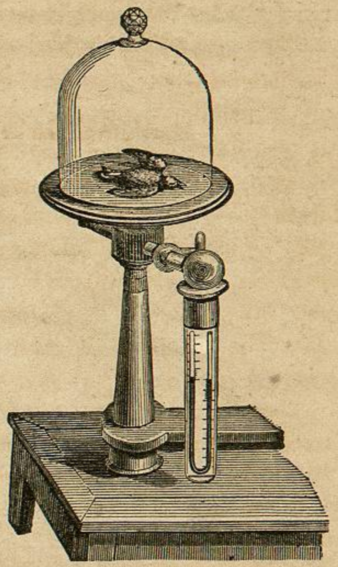

Fig. 90.

Animals and birds die as soon as they are placed in a vacuum; reptiles support life longer when deprived of air; as to certain insects, they live for many days under an exhausted receiver. They are enabled to live on the small supply of air which remains in the receiver, after as much of it as possible is extracted.

Preservation of Food in a Vacuum.

128. It has been discovered that articles of food which would soon perish if exposed to the air, may be preserved fresh for a long time if kept in a vacuum.

If fruits, vegetables, and the like, be placed in a bottle with water, and then heated gradually till ebullition takes place, all of the air will be driven out, being replaced by steam. If the bottle is corked and sealed in this condition, the fruit will remain fresh for years. On this principle, vast quantities of meat, fruit, vegetables, and the like, are prepared for naval and other purposes. Instead of bottles, tin canisters may be employed, which, after expelling the air, are hermetically sealed by soldering.

(**127.**) *How is it shown that air is necessary to combustion and animal life? What animals support life longest in a vacuum?* (**128.**) *How are articles of food preserved in vacuo? What applications are made of this principle?*

The Condenser.

129. A CONDENSER is a machine for condensing air, by forcing large quantities into a small space.

Such a machine is represented in Fig. 91. It is similar to the air-pump in its general construction, but differs in some of its details. The receiver is of very thick glass, and is

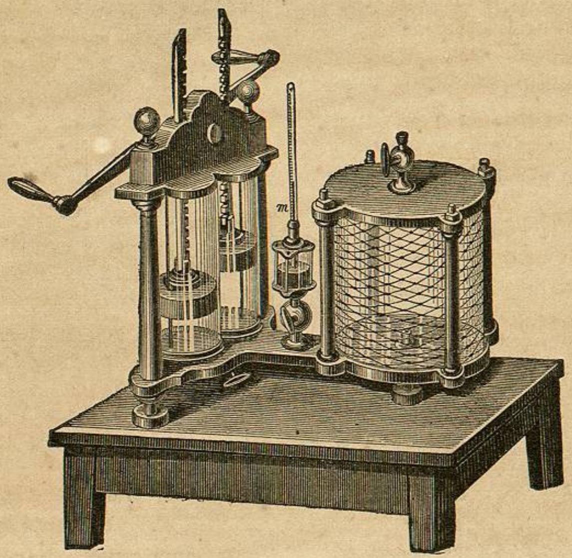

Fig. 91.

confined upon the plate by a second plate at the top, which is connected with the bottom plate by four brass rods with suitable screws and nuts. To prevent danger in case of rupture, the glass receiver is surrounded by a netting of strong wire. The four valves open in a direction contrary to that of the valves in the air-pump, so that air is forced

(**129.**) What is a Condenser? Difference between it and the air-pump? How is the receiver guarded?

into the receiver at every double stroke, instead of being exhausted, as in that instrument. Finally, a closed manometer, *m*, is employed to indicate the tension of the compressed air. The machine is worked in the same way as the air-pump.

A taper burns more freely in compressed air than in the air under the ordinary pressure. Animals placed in compressed air do not experience any extraordinary inconvenience. In many submarine operations, it becomes necessary for men to work in an atmosphere of compressed air, and it has been found that no other inconvenience is felt under a pressure of these atmospheres, than a painful sense of compression in the ears. This feeling only takes place at the beginning and end of the operations, disappearing when an equilibrium is established between the tension of the air in the internal ear and that without.

Artificial Fountains.

130. An ARTIFICIAL FOUNTAIN, is a machine by means of which water is forced upward in the form of a jet by the tension of compressed air. The most interesting instrument of this class, is that known as HERO's fountain, so named from its inventor, HERO, of Alexandria, born 120 B. C.

Hero's Fountain.

131. An ornamental form of HERO's FOUNTAIN is shown in Fig. 92. It consists of two globes of glass, connected by two metallic tubes. The upper globe is surmounted by a brass basin, connected with the globes by tubes, as shown in the figure.

To use the instrument, the tube which forms the jet is withdrawn, and through the opening thus made, the upper globe is nearly filled with water, the lower one containing air only. The jet tube is then replaced, and some water is poured into the basin.

How is the degree of condensation measured? *What effect has condensed air on combustion? On animal life? On divers?* (**130.**) What is an Artificial Fountain? (**131.**) Describe HERO's Fountain. How is it prepared for use?

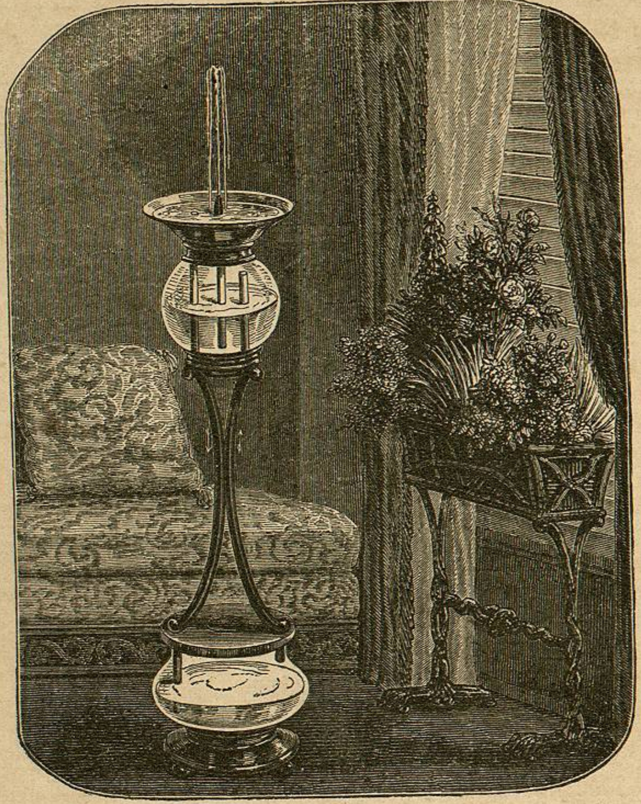

Fig. 92.

The water in the basin, acting by its weight, flows into the lower globe, through the tube shown on the left of the figure, as indicated by the arrow head. This flow of water into the lower globe forces out a part of the air in it, which, ascending by the tube shown on the right of the figure, accumulates in the upper globe. The pressure of the air in the upper globe, acting upon the water in that part of

Explain its action.

the instrument, forces a part of it up through the *jet tube*, giving rise to a jet of water, which may be made to play for several hours without re-filling the instrument.

Intermittent Fountain.

132. An Intermittent Fountain is one in which the flow is intermittent, that is, in which the flow takes place at regular intervals. Such fountains exist in nature. Fig. 93 represents an artificial fountain of this character.

Fig. 93.

(**132.**) What is an Intermittent Fountain?

It consists of a glass globe, *a*, closed above by a glass stopper, and having two small tubes below, through which water can flow without interruption. The globe *a*, is supported by a hollow glass stem, *d*, which, rising from a metallic basin, enters the globe and reaches nearly to the top of it. Around the bottom of the tube *d*, are small holes, *c*, through which air can enter it, and thus reach the upper part of the globe *a*. A small spout, *m*, serves to draw off the water from the basin.

To use the instrument, the globe *a*, and the metallic basin, are nearly filled with water. So long as the holes, *c*, are covered with water, no flow will take place from the globe *a*, but as soon as the basin is emptied by the spout *m*, so as to expose the holes, *c*, the air enters the tube *d*, and reaching the globe *a*, the flow from the two tubes commences. The flow will continue until the holes, *c*, are again submerged, when it will cease, and so on as long as any water remains in the globe.

Of course the capacity of the two tubes, attached to the globe *a*, must be greater than that of the spout *m*.

The Atmospheric Inkstand.

133. An inkstand has been devised in accordance with the principles of atmospheric pressure, which, whilst preserving the ink from evaporation, is extremely simple in its construction.

The inkstand, partially filled with ink, is represented in Fig. 94. The body of the inkstand is air-tight. Near the bottom is a tube for supplying the ink as wanted, and also for filling the inkstand when necessary. The inkstand is filled by turning it until the tube is at the top, when the

Describe the artificial one shown in Fig. 93. Explain its action. (**133.**) Explain the construction and use of the Atmospheric Inkstand.

ink can be poured in through the tube. The pressure of the atmosphere prevents the ink from flowing out. When the ink has been used till its level falls below *o*, where the tube joins the main body of the inkstand, a bubble of air enters, and rising to the top, acts by its pressure to fill the tube again, and so on until the ink is exhausted.

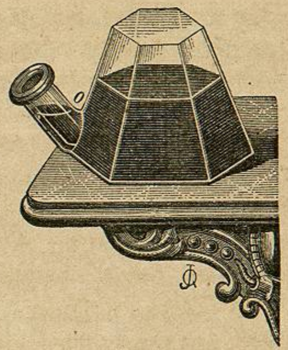

Fig. 94.

Water Pumps.

134. A Water Pump is a machine for raising water from a lower to a higher level, generally by the aid of atmospheric pressure. Three separate principles are employed in working pumps: the *sucking*, the *lifting*, and the *forcing* principles. Pumps are often named according as one or more of these principles are employed.

The Sucking and Lifting Pump.

135. A Sucking and Lifting Pump is represented in Fig. 95, in which a portion of the barrel is removed, to show more clearly the relative position of the parts.

It consists of a cylinder, usually of cast iron, called the *barrel* of the pump. The barrel communicates with a reservoir by a narrow pipe, called the *sucking pipe*, a part of which is shown in the figure. At the top of the sucking pipe is a valve opening upwards, called the *sleeping valve.* Within the barrel is a disk of metal or wood, packed with leather, called the *piston.* The piston is attached to a rod, *b*, called the *piston rod*, and is moved up and down through

(**134.**) What is a Water Pump? How many principles may be employed? What are they? How are pumps named? (**135.**) Describe the Sucking and Lifting Pump. Its barrel. Sucking pipe. Sleeping valve. Piston.

a certain space, called the *play* of the piston, by a lever, *B*, called the *pump-handle*. To cause the rod to work vertically, it is connected with the handle by a forked piece,

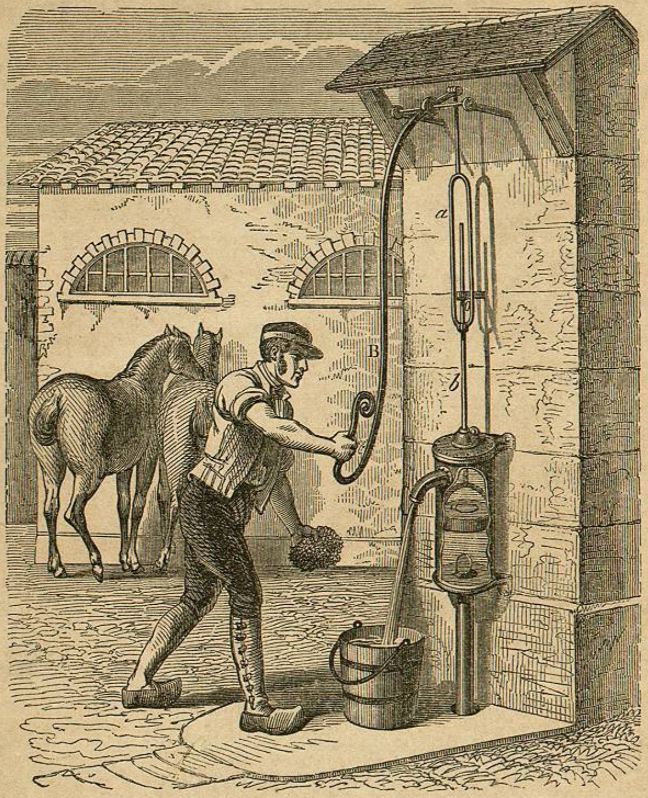

Fig. 95.

which is united to the piston rod by a hinge joint. This arrangement permits the rod, *b*, to glide up and down through a *guide*, as shown in the figure. Finally, the piston

Play of the piston. Piston rod. Guide.

itself is pierced in its centre, and carries a second valve, also opening upward, called the *piston valve*.

In explaining the action of this pump, we refer to Figs. 96, 97, and 98, which represent sections of the pump in different states of action. In all of the figures, *a* is the sleeping valve, *c* the piston valve, and *B* the sucking pipe.

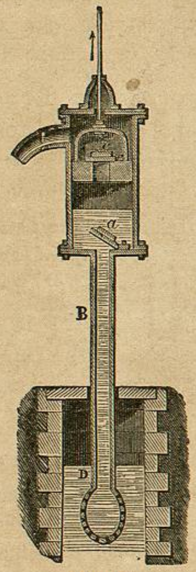

Fig. 96.

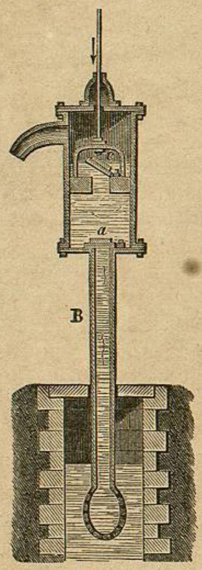

Fig. 97.

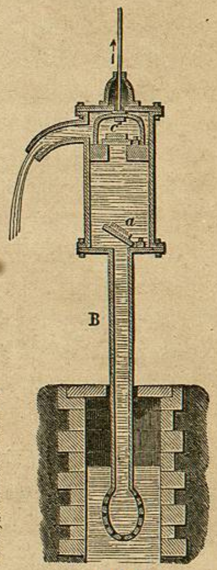

Fig. 98.

Suppose the piston to be at the lowest point of its play; there will then be an equilibrium between the pressure of the air within the pump and that without. When the piston is raised to the highest point of its play, the air beneath it is rarefied, and its tension diminished; the tension of the air in the sucking pipe then forces up the sleeping valve, and a portion of it escapes into the barrel. The tension of the air in the sucking pipe being less than that of

Piston valve. Explain the action of this pump.