tened with glycerine. Thus the pipette, in moving up and down, is not only firmly clasped by the india-rubber, but it also passes through a stuffing box of sticky cotton wool. The width of the aperture closed by the india-rubber secures the free lateral play of the lower end of the pipette. Into two other small apertures in the top of the cupboard are inserted, air-tight, the open ends of two narrow tubes intended to connect the interior space with the atmosphere. The tubes are bent several times up and down so as to intercept and retain the particles carried by such feeble currents as changes of temperature might cause to set in between the inner and the outer air (see Fig. 11).

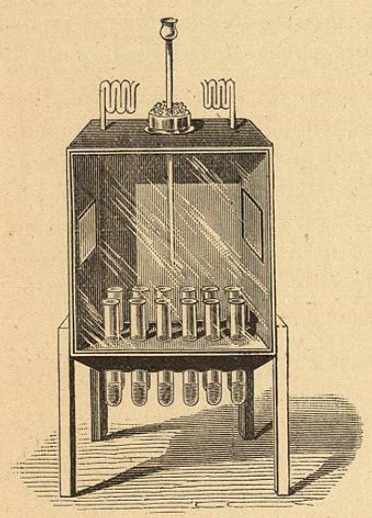

FIG. 11.—PROF. TYNDALL'S PURE CHAMBER (COPIED FROM TYNDALL).

'The bottom of the box is pierced with holes, in which are fixed, air-tight, twelve test tubes, intended to contain the liquid to be exposed to the action of the moteless air.'

The case so prepared is closed and allowed to stand for three or four days, till it is found by the beam of light that all the dust has settled. Then, the pipette being dipped into the test tubes, the fluid to be experimented on is introduced into each in succession. They are then boiled for five minutes in a brine bath. During the cooling, plugs of cotton wool are introduced into the small external convoluted tubes, but these plugs are afterwards withdrawn. The apparatus is then kept at a suitable temperature and at perfect rest. At the same time a part of the same infusion boiled for the same length of time is placed outside the box in free contact with the air.

In this way Tyndall has been able to preserve for an indefinite time, boiled urine, mutton infusion, beef infusion, haddock infusion, turnip infusion, hay infusion, infusion of sole, liver infusion, infusion of hare, rabbit, pheasant, grouse, codfish, turbot, herring, mullet, fowl and kidney; while flasks containing the same infusions, left exposed to the air after boiling for the same length of time, invariably putrefied in a few days.

This experiment, though resembling in many respects Pasteur's experiment with the flasks with long bent necks, differs from it materially. In Pasteur's experiment the whole of the interior of the vessel is acted on by the heat, and thus when the boiling is ended there is no part of the flask, except the neck, which contains any particles capable of causing fermentation. In this case, however, the steam from the tubes, passing into a larger chamber, is not able to destroy the vitality of the dust lining the walls of that chamber, and therefore the infusion is here not only in contact with ordinary air which has not been acted on by heat nor filtered of its dust, but the septic dust itself is present in the same vessel though not in actual contact with the fluids. Tyndall found that as soon as ordinary laboratory air, laden with dust, was admitted, putrefaction commenced.

Tyndall has further shown that the gases arising from putrefying substances, however foul smelling, cannot produce decomposition in other fermentescible liquids, although this readily occurs when ordinary dust is admitted.

Thus, 'on the 30th of November a quantity of animal refuse, embracing beef, fish, rabbit, hare, was placed in two large test tubes, opening into a protecting chamber containing six tubes. On December 13th, when the refuse was in a state of noisome putrefaction, infusion of whiting, turnip, beef, and mutton were placed in the other four tubes; they were then boiled and abandoned to the action of the foul sewer gases emitted by their two putrid companions. On December 25th these tubes were still unchanged. On the same day the end of the pipette was dipped into one of the putrid tubes and then inserted into the turnip, and on the 27th a similar speck was transferred to the whiting. These rapidly underwent decomposition, while the remaining two tubes remained unaltered.'

By operating in the manner described by Mr. Lister I have succeeded equally well in preserving fresh milk, meat, cucumber or turnip infusion for any length of time. As I shall have to refer at a later period to experiments in which extensive use is made of the ease with which these fluids can be preserved though retaining great readiness to undergo fermentation, I need not say more at present.

Not only is air which has been filtered incapable of causing fermentation in a boiled liquid, but air which has been

acted on by carbolic acid is also without effect. I may mention a few facts made out by myself in support of this statement.

In the small room in which most of my experiments were done it was almost impossible for me to transfer fluids from one flask to another, by Mr. Lister's method, without contamination and subsequent fermentation, but if I performed the same manipulations in a spray of about 1 to 30 carbolic acid and water I could transfer all sorts of fluids with ease from one flask to another without any risk, even though done in the most leisurely manner. In doing this I have used Mr. Lister's double-necked flasks without the protection of the india-rubber cap. I have also in a few instances simply poured the fluid from one single-necked flask to another, and when this was done in a carbolic acid spray without other precaution, the fluid remained pure.

That milk once rendered barren by boiling can be readily preserved for any length of time, though retaining its capability for undergoing fermentation, is shown by the following experiment.

On January 30th milk was prepared by boiling for twenty minutes in a flask purified by boiling distilled water in it under a cotton cap, the flask being afterwards dried by heat.

On the same afternoon three purified tubes with glass caps and shades (just like Mr. Lister's liqueur glasses) were half filled with this milk under the spray.

February 6.—The caps were removed under the spray, and a heated needle being introduced, portions of the fluid were taken from each tube for microscopical examination. All the milks were found to present the normal appearance of fresh milk externally and microscopically.

February 11.—Examined as before. No change.

February 19.—No change.

March 3.—Still fluid and unchanged in appearance. Two of the tubes were now tested by the addition of a drop of fluid from a tube containing milk which had been left open, and which had putrefied. In three days the milk in these two flasks had separated into two layers, and had lost its normal characters.

April 11.—The milk in the third test tube still remains unchanged.

I might multiply instances to show that milk and other fermentescible fluids can be kept in this way for months at a

suitable temperature, without undergoing any change. This is not due to any effect of the carbolic acid on the milk, because milk so preserved rapidly undergoes fermentation when exposed to the air. Indeed the minute quantity of the solution which comes in contact with it can have no effect whatever, as is shown by the following experiment performed in 1877.

February 1.—Five pure test tubes were taken and into each was introduced 100 minims of boiled milk, along with a certain number of minims of watery solution of carbolic acid, 1–20.

To No. I. were added 2 mins., making a proportion of 1–1000.
„ II. „ 5 „ „ „ 1–400.
„ III. „ 10 „ „ „ 1–200.
„ IV. „ 20 „ „ „ 1–120.
„ V. „ 50 „ „ „ 1–60.

They were then shaken up and left exposed to the air for twenty-four hours, and afterwards covered with very loosely-fitting caps, which were removed at intervals during the following day.

February 6.—The milks were beginning to alter in appearance and to separate into layers. This was the case even in No. V.

April 19.—They were all much advanced in decomposition.

Thus we see that decanting can be safely done in a spray of carbolic acid, the fluid still remaining as putrescible as ever; while, on the other hand, experience had taught me that in the particular room to which I have referred, it was very difficult to decant successfully without the spray.

The following experiment which I performed some time ago directly proves the efficacy of the spray:—

Two flasks containing pure milk were opened in my room, and left open for ten minutes. In both bacteria developed. As soon as these flasks were removed two other flasks similarly charged were put in the same place in a fine cloud of carbolic spray. They were opened and left open for ten minutes. Both of these remained pure, though when inoculated at a later period organisms rapidly developed in them. When they were removed the spray was stopped, and two fresh flasks were placed in the same position, opened and left open for ten minutes. One of the latter remained pure; in the other organisms appeared. (As will be later seen, the presence of organisms is synonymous with the presence of fermentation, and their absence with the absence of such changes.)

Another experiment proves to demonstration the efficacy of the spray in destroying the putrefactive agents in the air :—

Four flasks provided with cotton caps were purified according to Mr. Lister's method. Into two of these, pure cucumber infusion was introduced in the manner already described. These two flasks were placed for four days in an incubator, kept at the temperature of 98° F. At the end of this time the fluid was unchanged in both. About half of the liquid in one of the flasks was then poured into one of the empty previously purified flasks, in a cloud of carbolic spray, and the caps reapplied. These were then placed in the incubator and they remained permanently unchanged, and without the development of organisms. The same process was gone through with the two flasks without the use of a spray. In both of these organisms developed and putrefactive changes occurred.

In this experiment, when the fluid was poured from one vessel to the other it passed through the air, and air also entered into the first flask to take the place of the liquid. When this air had not been acted on by carbolic acid, organisms developed and fermentation took place, but where the air had previously passed through the spray it failed to cause any further change. (I do not of course mean to imply that the former will be a constant result, for in ordinary air there are but few organisms present, and probably many flasks would escape. This experiment refers to the air of the room in which it was performed, that air being loaded with causes of fermentation.)

A very striking proof of the value of the carbolic acid spray which occurred to me lately may be mentioned. The flasks which I at that time used were purified by heating them to a temperature of about 600° F. in a box like that described by Mr. Lister. The flasks were in the first instance heated without any covering, the cotton caps were then applied under the spray, and the flask with its cap reintroduced into the box, where it was thoroughly dried in order to drive off any carbolic acid which might be adhering to it. As the temperature to which the apparatus was in the first instance raised chars cotton wool, I used asbestos to filter the air as it passed into the interior of the box during cooling. For a while this answered quite well, but after a time portions of the asbestos became detached, and holes were thus formed through which air could

enter without being filtered, and as a result on several occasions I found that all the flasks so prepared were impure. This was obviated simply by directing the spray against the door of the box as soon as the lamp which heats it was extinguished. The box was thus surrounded by spray; the air passing into it first passed through this spray, and, as a result, since I did this, I never failed in any instance in obtaining pure flasks.[1]

From these researches we learn that the gases of the air, whether oxygen, nascent oxygen, ozone, nitrogen, carbonic acid, emanations from fermenting substances, &c., are powerless to cause fermentation in boiled fluids or tissues. Further, that it is sufficient, in order to prevent this occurrence, that the air be either previously heated, or filtered through cotton wool, or acted on by chemical substances, such as sulphuric acid or carbolic acid, or merely allowed to remain at rest so as to permit the dust to settle outside the substance tested. It is therefore evident that the causes of putrefaction in *boiled* substances are solid particles present in the atmosphere and on surrounding objects, which may be deprived of their fermentative properties in various ways. When we come to consider the further questions of spontaneous generation and the relation of organisms to fermentative changes, we shall find much additional evidence confirming this view.

[1] The exact merits of the carbolic spray as a means of purifying the atmosphere will be discussed later. What I wish to point out here is, that in ordinary air, in circumstances where we know that particles capable of causing fermentation are present, carbolic acid is able to render these particles inert.