one thing to refute a proposition and another to prove the truth of a doctrine which implicitly, or explicitly, contradicts that proposition; and the advance of science soon showed that, though Needham might be quite wrong, it did not follow that Spallanzani was quite right.

Modern Chemistry, the birth of the latter half of the eighteenth century, grew apace, and soon found herself face to face with the great problems which Biology had vainly tried to attack without her help. The discovery of oxygen led to the laying of the foundations of a scientific theory of respiration, and to an examination of the marvelous interactions of organic substances with oxygen. The presence of free oxygen appeared to be one of the conditions of the existence of life, and of those singular changes in organic matters which are known as fermentation and putrefaction. The question of the generation of the infusory animalcules thus passed into a new phase. For what might not have happened to the organic matter of the infusions, or to the oxygen of the air, in Spallanzani's experiments? What security was there that the development of life which ought to have taken place had not been checked, or prevented, by these changes?

The battle had to be fought again. It was needful to repeat the experiments under conditions which would make sure that neither the oxygen of the air, nor the composition of the organic matter, was altered, in such a manner as to interfere with the existence of life.

Schulze and Schwann took up the question from this point of view in 1836 and 1837. The passage of air through red-hot glass tubes, or through strong sulphuric acid, does not alter the proportion of its oxygen, while it must needs arrest or destroy any organic matter which may be contained in the air. These experimenters, therefore, contrived arrangements by which the only air which should come into contact with a boiled infusion should be such as had either passed through red-hot tubes or through strong sulphuric acid. The result which they obtained was, that an infusion so treated developed no living things, while, if the same infusion was afterwards exposed to the air, such things appeared rapidly and abundantly. The accuracy of these experiments has been alternately denied and affirmed. Supposing them to be accepted, however, all that they really proved was, that the treatment to which the air was subjected destroyed *something* that was essential to the development of life in the infusion. This "something" might be gaseous, fluid, or solid; that it consisted of germs remained only an hypothesis of greater or less probability.

Cotemporaneously with these investigations, a remarkable discovery was made by Cagniard de la Tour. He found that common yeast is composed of a vast accumulation of minute plants. The fermentation of must, or of wort, in the fabrication of wine or of beer is always accompanied by the rapid growth and multiplication of these *Torulæ*. Thus, fermentation, in so far as it was accompanied by the development of microscopial organisms in enormous numbers, became assimilated to the decomposition of an infusion of ordinary animal or vegetable matter; and it was an obvious suggestion that the organisms were, in some way or other, the causes both of fermentation and of putrefaction. The chemists, with Berzelius and Liebig at their head, at first laughed this idea to scorn; but, in 1843, a man, then very young, who has since performed the unexampled feat of attaining to high eminence, alike in mathematics, physics, and physiology—I speak of the illustrious Helmholtz—reduced the matter to the test of experiment by a method alike elegant and conclusive. Helmholtz separated a putrefying, or a fermenting, liquid, from one which was simply putrescible or fermentable, by a membrane, which allowed the fluids to pass through and become intermixed, but stopped the passage of solids. The result was that, while the putrescible, or the fermentable, liquids became impregnated with the results of the putrescence, or fermentation, which was going on at the other side of the membrane, they neither putrefied (in the ordinary way) nor fermented; nor were any of the organisms which abounded in the fermenting or putrefying liquid generated in them. Therefore, the cause of a development of these organisms must lie in something which cannot pass through membrane; and as Helmholtz's investigations were long antecedent to Graham's researches upon colloids, his natural conclusion was that the agent thus intercepted must be a solid material. In point of fact, Helmholtz's experiments narrowed the issue to this: That which excites fermentation and putrefaction, and at the same time gives rise to living forms in a fermentable or putrescible fluid, is not a gas and is not a diffusible fluid; therefore, it is either a colloid, or it is matter divided into very minute solid particles.

The researches of Schroeder and Dusch, in 1854, and of Schroeder alone, in 1859, cleared up this point by experiments which are simply refinements upon those of Redi. A lump of cotton-wool is, physically speaking, a pile of many thicknesses of a very fine gauze, the fineness of the meshes of which depends upon the closeness of the compression of the wool. Now Schroeder and Dusch found that in the case of all the putrefiable materials which they used (except milk and yolk of egg), an infusion boiled, and then allowed to come into contact with no air but such as had been filtered through cotton-wool, neither putrefied nor fermented, nor developed living forms. It is hard to imagine what the fine sieve formed by the cotten-wool could have stopped except minute solid particles. Still the evidence was incomplete until it had been positively shown, first, that ordinary air does contain such particles; and, secondly, that filtration through cotton-wool arrests these particles and allows only physically pure air to pass. This demonstration has been furnished within the last year by the remarkable experiments of Professor Tyndall. It has been a common objection of Abiogenesists that, if the doctrine of Biogeny is true, the air must be thick with germs; and they regard this as the hight of absurdity. But nature is occasionally exceedingly unreasonable, and Professor Tyndall has proved that this particular absurdity may, nevertheless, be a reality. He has demonstrated that ordinary air is no better than a sort of stirabout of excessively minute solid particles; but these particles are almost wholly destructible by heat; and that they are strained off, and the air rendered optically pure, by being passed through cotton-wool.

But it remains yet in the order of logic, though not of history, to show that, among these solid destructible particles, there really do exist germs capable of giving rise to the development of living forms in suitable menstrua. This piece of work was done by M. Pasteur in those beautiful researches which will ever render his name famous; and which, in spite of all attacks upon them, appear to me now, as they did seven years ago, to be models of accurate experimentation and logical reasoning. He strained air through cotton-wool, and found, as Schroeder and Dusch had done, that it contained nothing competent to give rise to the development of life in fluids highly fitted for that purpose. But the important further links in the chain of evidence added by Pasteur are three. In the first place, he subjected to microscopic examination the cotton-wool which had served as strainer, and found that sundry bodies, clearly recognizable as germs, were among the solid particles strained off. Secondly, he proved that these germs were competent to give rise to living forms by simply sowing them in a solution fitted for their development. And, thirdly, he showed that the incapacity of air strained through cotton-wool to give rise to life, was not due to any occult change effected in constituents of the air by the wool, by proving that the cotton-wool might be dispensed with altogether, and perfectly free access left between the exterior air and that in the experimental flask. If the neck of the flask is drawn out into a tube and bent downwards; and if, after the contained fluid had been carefully boiled, the tube is heated sufficiently to destroy any germs which may be present in the air which enters as the fluid cools, the apparatus may be left to itself for any time, and no life will appear in the fluid. The reason is plain. Although there is free communication between the atmosphere laden with germs and the germless air in the flask, contact between the two takes place only in the tube; and as the germs cannot fall upwards, and there are no currents, they never reach the interior of the flask. But if the tube be broken short off where it proceeds from the flask, and free access be thus given to germs falling vertically out of the air, the fluid which has remained clear and desert for months, becomes, in a few days, turbid and full of life.

These experiments have been repeated over and over again by independent observers with entire success; and there is one very simple mode of seeing the facts for oneself, which I may as well describe.

Prepare a solution (much used by M. Pasteur, and often called "Pasteur's solution") composed of water with tartrate of ammonia, sugar, and yeast-ash dissolved therein Divide it into three portions in as many flasks; boil all three for a quarter of an hour; and, while the steam is passing out, stop the neck of one with a large plug of cotton wool, so that this also may be thoroughly steamed. Now set the flasks aside to cool, and when their contents are cold, add to one of the open ones a drop of filtered infusion of hay, which has stood for twenty-four hours, and is, consequently, full of the active and excessively minute organisms known as *Bacteria*. In a couple of days of ordinary warm weather, the contents of this flask will be milky, from the enormous multiplication of *Bacteria*. The other flask, open and exposed to the air, will, sooner or later, become milky with *Bacteria*, and patches of mold may appear in it; while the liquid in the flask, the neck of which is plugged with cotton wool, will remain clear for an indefinite time. I have sought in vain for an explanation of these facts, except the obvious one, that the air contains germs competent to give rise to *Bacteria*, such as those with which the first solution has been knowingly and purposely inoculated, and to the mold *fungi*. And I have not yet been able to meet with any advocate of Abiogenesis who seriously maintains that the atoms of sugar, tartrate of ammonia, yeast-ash, and water, under no influence but that of free access of air and the ordinary temperature, re-arrange themselves and give rise to the protoplasm of *Bacterium*. But the alternative is to admit that these *Bacteria* arise from germs in the air; and if they are thus propagated, the burden of proof, that other like forms are generated in a different manner, must rest with the assertor of that proposition.

[Remainder next week].

Another Case of Spontaneous Combustion.

The recent great fire in Chicago is now supposed to have been spontaneously originated in a bundle of greasy rags. How long will it be before people generally understand that such rags are dangerous? The general carelessness in the storage of these and similar dangerous substances is only equaled by that in the domestic use of matches. We saw a business man the other day throw without thinking an unextinguished match into his paper waste basket. We not unfrequently step on matches in walking through public buildings or on the ferry boats which detonate under our feet. How many men, women, or children when they drop a match never think of stooping to pick it up, but take a new one from the box, rather than subject themselves to a slight inconvenience, which might perhaps prevent the destruction of thousands of dollars' worth of property. To always extinguish matches before throwing them away, and always pick them up when dropped, are habits which should be taught to every child.

THE MANUFACTURE OF SOLUBLE GLASS.

[From Feuchtwanger's "Treatise on Soluble Glass."]

The potash soluble glass is obtained by mixing 15 parts powdered quartz or pure sand with 10 parts purified pearl ashes, and 1 part charcoal in a Hessian crucible, and exposing the mixture so long to a heat until the mass after six hours has become vitrified. Charcoal is employed for assisting, by its decomposition, the production of carbonic acid, as also some sulphuric acid which may have been produced. It is at present, however, omitted, and if manufactured on a large scale the vitrification is done in a reverberatory furnace capable of holding from 1,200 to 1,500 pounds. The ashes and sand must be well mixed togther for some time and the furnace must be very hot before throwing the mixture in it, and the heat must be constantly kept up until the entire mass is in a liquid condition. The tough mass is then raked out and thrown upon a stone hearth and left to cool. The glass mass so obtained appears to be hard and blistery, of blackish gray color, and if the ashes were not quite pure it will also be adulterated with foreign salts. By pulverizing and exposing it to the air it will absorb the acidity, and by degrees the foreign salts will, after frequent agitation and stirring, be completely separated, particularly after pouring over the mass some cold water, which dissolves them, but not the soluble glass. The purified mass is now put into an iron cauldron, containing five times the quantity of hot water, in small portions, and with constant agitation, and replacing occasionally hot water for that which evaporated during the boiling, and after five or six hours the entire mass is dissolved; the liquid is removed and left to settle over night, in order to be able to separate any undecomposed silex. The next day it is evaporated still more until it has assumed the consistency of a sirup, and standing 28° B. and is composed of 28 per cent potash, 62 per cent silica, and 12 per cent water. It has an alkaline taste, and is soluble in all proportions of water, and is precipitated by alcohol, and if any salts do effervesce they may be wiped off. The color is not quite white, but assumes a greenish or yellowish white color.

MANUFACTURE OF SODA SOLUBLE GLASS.

To 45 parts silica or white river sand are added 23 parts carbonate of soda fully calcined, and 3 parts charcoal, and is then treated in the same manner as the other glass. The proportions of the mixture are altered by the different manufacturers, some propose to 100 parts silex, 60 parts anhydrous glauber salt, and 15 to 20 parts charcoal. By the addition of some copper scales to the mixture, the sulphur will be separated. Another method is proposed by dissolving the fine silex in caustic soda lye. Kuhlman employs the powdered flint, which is dissolved in an iron cauldron under a pressure of 7 to 8 atmospheres. According to Liebig the infusorial earth is recommended in place of sand on account of being readily soluble in caustic lye, and he proposes to use 120 parts infusorial earth to 75 parts caustic soda, from which 240 parts silica jelly may be obtained. His mode is to calcine the earth so as to become of white colors, and passing it through sieves. The lye he prepares from 75 ounces calcined soda, dissolved in five times the quantity of boiling water, and then treated by 56 ounces of dry slacked lime; this lye is concentrated by boiling down to 48 deg. B.; in this boiling lye 120 ounces of the prepared infusorial earth are added by degrees, and very readily dissolved, leaving scarcely any sediment. It has then to undergo several operations for making it suitable for use, such as treating again with lime water, boiling it, and separate any precipitate forming thereby, which by continued boiling forms into balls, and which can then be separated from the liquid. This clear liquid is then evaporated to consistency of sirup, forms a jelly slightly colored, feels dry and not sticky, and is easily soluble in boiling water.

The difference between potash and soda soluble glass is not material; the first may be preferred in whitewashing with plaster of Paris, while the soda glass is more fluidly divisible.

It may be observed that before applying either soluble glass, it ought to be exposed to the air for ten to twelve days, in order to allow an efflorescence of any excess of alkali, which might act injuriously.

DOUBLE SOLUBLE GLASS.

This is a compound of potash and soda, and is prepared from 100 parts quartz, 28 parts purified pearl ashes, 22 parts anhydrous bicarbonate of soda, and 6 parts of charcoal, which are spread in such manner as already described. If the mass is fully evaporated to dryness, it forms a vitreous solid glass which cannot be scratched by steel, has a conchoidal fracture, of sea-green color, translucent and even transparent, and has specific gravity of 1·43.

Soluble glass, after Kaulbach, for the use of sterro-chromic painting, is obtained by fusing 3 parts of pure carbonate soda and 2 parts powdered quartz, from which a concentrated solution is prepared, and 1 part of which is then added to 4 parts of a concentrated and fully saturated solution of potash glass solution, by which it assumes a more condensed amount of silica with the alkalies; and which solution has been found to work well for paint. Siemen's patent for the manufacture of soluble glass, consists in the production of a *liquid quartz* by digesting the sand or quartz in a steam boiler tightly closed and at a temperature corresponding to 4–5 atmospheres, with the common caustic alkalies, which are hereby capacitated to dissolve from three to four times the weight of silica to a thin liquid. The apparatus, which was patented in 1845, is well known in this country; as some persons, many years later, obtained a patent for the same apparatus in the United States, which on inspection does not differ from that of Siemens Brothers.