# ANTISEPTIC SURGERY.

## CHAPTER I.

### THE PARTICULATE THEORY OF FERMENTATION. ON THE FERMENTATION OF BOILED SUBSTANCES.

Definition of putrefaction and fermentation—Chemical fermentations—Living ferments—Various views on fermentation—Lavoisier—Fabroni—Thenard—Appert—Gay-Lussac's experiments and conclusions—Caignard-Latour—Schwann, heated air inert—Schulze—Ure and Helmholtz, nascent oxygen inert—Liebig's views—Review of the subject—Schroeder and Dusch, filtered air inert—Schroeder, ozone inert—Schroeder's final views—Pasteur's researches—Lister—Roberts—Tyndall—My own results, carbolised air inert—Conclusions as to the cause of the fermentation of boiled substances.

THE term 'septic' so much used in surgery at the present day is derived from the Greek word σηπτικὸς, which means something that *causes* putrefaction, the verb σήπω signifying to *cause* to rot, to *make* putrid. An 'antiseptic' is therefore, according to this derivation, something which acts against the *causes* of putrefaction, and 'Antiseptic Surgery' is surgery directed not against its *effects* but against its *causes*. In dealing, then, with the subject of antiseptic surgery, we must first enquire what is putrefaction, and how is it brought about?

Putrefaction is now held to be a form of fermentation accompanied by the development of offensive odours, and fermentation may be defined as 'a new arrangement of the elements of an organic compound (often with the assimilation of the elements of water), and the consequent formation of new products.' (Fownes.)

Changes coming under the above definition of fermentation have been long known as the result of what is termed Catalysis. Of this perhaps the best example is the change effected in Amygdalin by the action on it of Emulsin. As a result of the contact of these two bodies in presence of water, the amygdalin is broken up into various products, of which the chief are hydrocyanic acid and oil of bitter almonds. This decomposition of amygdalin is, however, not effected by *combination* with emulsin, for the latter remains unchanged, although its presence is necessary for the chemical action. Similar facts are known with regard to the Pepsin of the gastric juice, the Ptyalin of saliva, the pancreatic ferment, &c. But although these ferments undergo little or no change, yet nevertheless it has been clearly proved that they have not the power of self-multiplication. Hence these ferments generally receive the name of 'chemical' ferments.

There is, however, another class of ferments which possess this power of self-multiplication in a remarkable degree. An instance of this may be given in the alcoholic fermentation. Here a minute piece of yeast is introduced into grape juice, or into a sugary solution, and as a result fermentation soon sets in, and goes on slowly till the sugar is decomposed. If we compare this process with the former we see two marked points of difference; in the first place, in the former the change is rapid and more or less instantaneous; in the latter it progresses slowly and steadily, and requires much more time for its completion. In the former there is no increase in quantity of the ferment; in the latter the increase is very marked, and when the fermentation has gone on for some time the minutest portion of the fermenting substance added to unfermented material of like composition produces in it a similar series of changes; and this multiplication of the ferment goes on continuously whenever it is brought in contact with fresh material. As this power of multiplication is a property of living things, the term 'vital' is usually applied to this class of ferments.

In one point the 'chemical' ferment is allied to the 'vital' ferment. It is not a substance as yet formed by the chemist. It is the product of living cells; and it is quite possible that the yeast plant may act in the same way as the salivary or



peptic cells, viz. by excreting a ferment which produces the change in the fermentescible substance, this ferment in neither case possessing the power of self-multiplication. In the case of the salivary ferment the cells which produce it are an integral part of a complex organism, and cannot live apart from the body; hence the ptyalin, introduced into starch, does not increase in amount. On the other hand, the yeast plant is an independent cell, and grows free in the fermenting fluid, and it is to the growth and multiplication of these living cells, and not to an increase in quantity of the chemical ferment as such, that the multiplication of the fermenting power is due.

In the putrefaction of discharges in wounds we have to deal with a ferment belonging to the same class as the alcoholic ferments—with a ferment capable of multiplication, which acts slowly and steadily, not suddenly. We must therefore enquire a little more fully into the nature of this class of ferments, into their origin and history, in order to obtain some principles to guide us in attempting to prevent their action.

In reviewing the history of this subject, the first research of any consequence which it is necessary for us to consider is that of Gay-Lussac.[1] Previous to the publication of this paper attempts had been made by Lavoisier, Fabroni, and Thenard to give some explanation of the process of fermentation.

Lavoisier's work was in the main carried out with the view of ascertaining the changes which a fermenting liquid undergoes.[2] He did not attempt to assign a definite cause for the process.

Fabroni,[3] writing on the subject of the alcoholic fermentation, concluded that fermentation was a decomposition of one substance by another, 'just as a carbonate is decomposed by an acid, or sugar by nitric acid. The substance which decomposes sugar is a vegeto-animal substance. It is contained in certain utricles in the grape. When the grape is crushed this material, which is of the nature of gluten, mixes with the sugar in the juice, and as soon as these two substances come into contact, effervescence or fermentation commences just as occurs in every

[1] *Annales de Chimie*, lxxvi. 1810.
[2] *Eléments de Chimie*, i. 2nd ed.
[3] *Annales de Chimie*, xxxi. 1799.

other chemical process, as, for instance, when an acid and a carbonate are mixed in the same vessel.'

Some years later, but ignorant of Fabroni's views, Thenard published a research on alcoholic fermentation,[1] in which he showed that gluten had no power whatever of causing the fermentation of sugar. He observed that during the process of fermentation, a deposit occurred which had the power of inducing a similar change in a fresh saccharine liquid. This substance was apparently the same in a great variety of liquids of different chemical composition, and it presented characters similar to those of yeast. Thenard states that he was unable to determine whether this substance was formed in the course of the fermentation, or whether it was in solution at the commencement and became deposited as a result of the changes which occurred. He, however, inclines towards the latter view.

Gay-Lussac was led to make his investigations by studying the procedure of M. Appert for preserving vegetable and animal substances.[2] Appert's method consisted in placing the materials to be preserved in bottles, very closely corked. These bottles were exposed to the temperature of boiling water for a longer or shorter period of time. They were then packed up and kept for use. There can be no doubt as to the efficiency of this method, for in Appert's work certificates are furnished by several scientific commissions, containing such names as Gay-Lussac, Bordel, &c.

Gay-Lussac noticed that, though the substances so prepared could be preserved unaltered for an indefinite period so long as the vessels were kept thoroughly closed, yet, as soon as the vessels were opened, and more especially if the substances were decanted into other vessels, their contents underwent fermentative changes.

To ascertain why this occurred, he took a flask of grape-juice which had been preserved for a year unaltered, and which was accordingly quite limpid. Having opened the flask he poured its contents into another vessel, which he closed very accurately and kept at the temperature of 15° to 30° C. Eight days later

[1] *Annales de Chimie*, xlvi. 1803.
[2] *The Art of Preserving Animal and Vegetable Substances.*



the juice had lost its transparency, fermentation had become established, and it soon became an alcoholic fluid. A second vessel containing grape-juice, prepared by Appert's method, was kept at the same temperature and in the same place, but unopened. This remained pure. This latter flask, the neck of which had been drawn out and sealed, was now taken, and a deep notch having been made with a file, its neck was plunged into mercury and then broken off. A portion of the contents was then introduced into a bell-jar containing no oxygen, and a second portion into one containing a small quantity of that gas. The first remained without change for forty days, while the second underwent fermentation very rapidly. In the latter flask all the oxygen had disappeared, but much more carbonic acid in proportion had been produced. Gay-Lussac therefore concluded that, although oxygen is necessary to initiate the fermentation, yet it is not essential for its continuance. The same results were obtained when currant-juice or freshly prepared grape-juice were used. Gay-Lussac further found that, if this juice after being transferred from one vessel to another were again heated after secure corking, it could again be preserved for an indefinite time. He observed that during the boiling the fluid lost its transparency and a deposit took place. He came to similar conclusions as to the necessity of oxygen for the initiation of fermentative processes, in the case of the putrefaction of meats, &c., preserved according to Appert's method.

Gay-Lussac concludes from his experiments that oxygen is necessary for the commencement of the fermentation; that this oxygen combines with some substance in the fermentescible fluid, thus producing the ferment, which can then act without further oxygen; that the effect of the heat in Appert's method is to decompose any combination already formed, and to make the oxygen which is present unite to form some substance which is not a ferment; that the product of this union with oxygen is the deposit which is seen to occur on heating these fluids. He however recognises that fermentation is still a mysterious process, since it occurs slowly and not immediately like other chemical actions.

Passing now over a period of some years, we come to the views of Caignard-Latour, made known in papers presented to the French Academy during the years 1835–37.[1] On examining fermenting grape-juice, he found (as indeed had been imperfectly observed before by Leuwenhoeck and Desmazières) that it contained numerous globular bodies which he considered to be of vegetable nature, and which he found to possess the power of reproduction, partly by budding and partly, as he supposed, by contracting and liberating numerous spores. From several facts—amongst others, from finding that in juices not undergoing alcoholic fermentation these bodies were absent, while they were always present where that fermentation occurred—he concluded that they were the cause of the fermentation. He further found that the deposit of which Thenard spoke, and which he had stated to be the ferment, was composed entirely of these bodies.

Similar views were announced almost simultaneously by Schwann,[2] and to him rather than to Caignard-Latour must be given the credit of having furnished the first real proof of the view that these cells were the causes of the fermentation.

Schwann prepared infusions of meat, fruits, &c., somewhat after Appert's method, but, instead of leaving the vessels completely sealed, he allowed air which had been previously heated to come in contact with the fluids. The following is his description of the method which he ultimately adopted.

'Into a three-ounce vessel a small piece of meat was introduced, and then water was added so that the whole occupied about one-fourth of the capacity of the vessel; the bottle was then closely corked, the cork being firmly fastened down by wire. This cork was traversed by two small glass tubes, one of which was at once bent downwards on its exit from the vessel, and its orifice dipped into a small beaker containing mercury covered by a layer of oil. The other tube ran at first horizontally and then directly downwards for an inch and a half. There it had two narrow spiral turnings, then it again ran upwards, and finally horizontally, being drawn out to a fine point at its termination. The cork was covered with several layers of a solution of caoutchouc in linseed oil, rendered thinner by the addition of oil of turpentine. The fluid in the flask was now boiled, and the steam was made to issue from the two tubes till the mercury and oil became so

[1] See *Annales de Chimie et de Physique*, t. lxviii. 2e série, 1838.
[2] *Poggendorf's Annalen*, xli. 1837.



hot that they no longer condensed the steam. (In order that no organisms might develop in the water which remained between the oil and the mercury, a layer of corrosive sublimate was placed between them.) While the boiling was going on a spirit lamp was placed under the spirals of the second tube, and the heat was continued until the tube began to soften (see Fig. 1). The drops of water condensing in the cooler parts of the tubes were dispelled by another lamp. After boiling had continued for a quarter of an hour it was stopped, and, during the cooling of the flask, air passed through the second glass tube into the vessel, being however previously heated in the spiral part of that tube. After complete cooling of the flask the orifice of this tube was sealed and the portion of the tube between the spiral and the end, containing unheated air, was heated. That being done the spirit lamp was completely removed.'

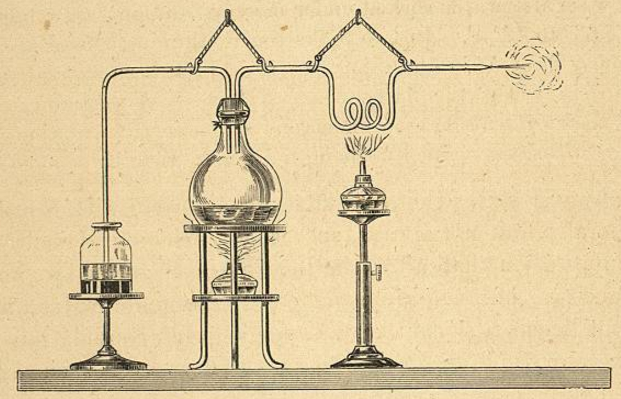

FIG. 1.—SCHWANN'S METHOD.

Prepared in this way, the flask contained only boiled meat infusion and heated air. From time to time this air was renewed in the following manner: the spiral part of the tube having been heated almost to melting, the point was broken and fresh air forced slowly in, the old air bubbling out through the mercury. After a time the tube was again sealed with the same precautions as before.

By operating thus Schwann succeeded in preserving meat and other substances at a temperature of 63° to 77° F. without any putrefaction, and without the appearance of organisms in them; while the same materials when exposed to ordinary air underwent putrefactive changes in a few days.

It was thus evident that there was a something present in the air, other than the gases of the air which had the power of bringing about fermentative changes in boiled liquids, and that this something could be destroyed by heat.

Some further experiments which Schwann performed with reference to the alcoholic fermentation furnish additional evidence against the view that the gases of the air are the causes of putrefaction.

A solution of cane sugar having been mixed with yeast, four flasks were quite filled with the mixture and then corked. These flasks were placed in boiling water for an equal length of time (ten minutes each). They were then inverted over heated mercury, and air was introduced so as to displace one-third to one-fourth of the fluid. The flasks were afterwards corked under mercury and kept at a temperature of 63° to 77° F. In two flasks the air thus introduced had been previously heated, in the other two it had not been so treated. In four to six weeks the flasks which had received the unheated air burst, their contents having undergone alcoholic fermentation. The other two flasks remained unchanged for more than three months.

Schwann states that this latter experiment with heated air is generally, but not always, successful, and he explains this by the supposition that after the heating of the mercury, and in the processes of uncorking and corking, organic matter, which had not been previously heated, might very possibly mix with the mercury and enter the flasks. (This view has since been proved to be correct by Pasteur.)

It is but fair to refer here to the experiments on spontaneous generation published in 1836 by Franz Schulze. These will be described at a later period. They are, however, of interest here, because Schulze anticipated Schwann in the principle of admitting air previously acted on in some way or other, in his case chemically, to Appert's preserves.

Schwann's experiments were repeated and confirmed by Ure in 1840[1] and by Helmholtz in 1843.[2] The latter author, in order to test the oxygen view still further, prepared an infusion in the usual manner in a vessel into which platinum electrodes were fixed. After the infusion had remained unaltered for some

[1] *Journal für praktische Chemie*, xix.
[2] *Müller's Archiv.* 1843.



time a current of electricity was sent through the liquid, decomposing the water into hydrogen and oxygen. But even this oxygen in its nascent, and therefore in its most active state, was unable to produce any fermentation in the fluid.

In the meantime Liebig had stepped forward as the opponent of the views advanced by Caignard-Latour and by Schwann. He proposed a theory of a totally different nature.[1] After pointing out that organic molecules have a tendency to alter their constitution, to break up and rearrange themselves, he approaches the question of putrefaction and fermentation. With regard to the cause of these changes he writes as follows: 'Cette cause est la faculté que possède un corps en décomposition ou en combinaison, c'est-à-dire, en action chimique, d'éveiller la même action dans un autre corps qui se trouve en contact avec lui, ou de le rendre apte à subir l'altération qu'il éprouve lui-même.' He compares this sort of action to combustion, and cites several well-known instances of this kind, such as the decomposition of nitric acid by an alloy of platinum and silver, a change which does not take place with the platinum alone; or the decomposition of peroxide of manganese by oxide of silver, &c., in water containing oxygen.

He includes under the term 'eremacausis,' the alterations which organic substances undergo at ordinary temperatures, and as the result of the action of oxygen. When oxygen is excluded, putrefaction occurs. Putrefaction is a combustion of one or more of the elements of the organic substances at the expense of their own oxygen. Where no foul smelling products result, the process is termed fermentation. Putrefaction occurs when the equilibrium of the attractions of a complex organic molecule is upset, and it results in a rearrangement of these elements. Non-nitrogenous organic substances do not undergo this putrefaction spontaneously when they are pure. They must be brought in contact with some substance already undergoing change. This latter substance is therefore termed a ferment. This ferment is a nitrogenous substance undergoing putrefaction and eremacausis, it converts the oxygen of the air into carbonic acid, &c. Its activity is destroyed by desiccation, by heat, alcohol, &c. It is the soluble portion of

[1] *Annales de Chimie et de Physique*, 2e série, lxxi. 1839.

the ferment which is active, and this does not act by direct contact, but in consequence of a decomposition which it itself undergoes. The elements of the ferment take no part in the formation of the products which sugar furnishes when fermented, though at the same time the ferment is itself undergoing destruction. (This latter statement is based on an observation by Thenard, who found that 20 parts of fresh yeast, added to 100 parts of sugar left, after fermentation was complete, only 13·7 parts of an insoluble residue. This residue placed in a new portion of sugar became reduced to 10 parts. This last residue no longer exerted any action. Pasteur has since completely disproved the accuracy of Thenard's results. On the contrary he finds that yeast increases markedly during fermentation, and in his latest work Liebig admits this.)

The ferment is, therefore, according to Liebig, a body undergoing decomposition. If the ferment is too small in quantity for the sugar, when the decomposition of the former is complete the latter ceases to ferment (this statement has since been shown to be quite erroneous), and therefore a sufficient quantity must be present in order that its decomposition may not be completed till that of the sugar has ended. No special substance is, according to this view, required in order to act as a ferment, but merely one which shall be the constant exciter of action in the fermentescible substance. (This statement is also wrong, because putrefying fluids and tissues added to sugary solutions do not convert the sugar into alcohol. This was latterly admitted by Liebig, who was compelled to allow the existence of some relation between the yeast plant and the alcoholic fermentation, a connection which he, however, attributed to the effect propagated from the dead and dying, not from the living, cells.)

Liebig sums up as follows:—

Organic compounds present two opposite and definite phenomena.

1. They give rise to bodies endowed with new properties, the elements of several molecules of a more simple compound uniting to form one molecule of a more complex nature.

2. Some complex molecules of a high degree of complexity break up into one or more less complex molecules of a lower order, in consequence of the destruction of the equilibrium of the attractions of their elements. This equilibrium may be destroyed by heat, by contact with a body of different composition, or by the action of a body which is itself undergoing change.



As an example of this Liebig takes the case of urine: 'In fresh urine,' he says, 'if oxygen be entirely excluded there occurs no alteration of the urea or of the hippuric acid contained in it, but if exposed to the air another substance present in the urine (probably the mucus) undergoes a change of form and composition (eremacausis), which is transferred or communicated to the urea and the hippuric acid; the urea is resolved into carbonic acid and ammonia; the hippuric acid disappears, and in its place is found benzoic acid.'

He continues: 'When we reflect that the power of exciting putrefaction belongs to bodies of the most different composition, that blood, flesh, cheese, saliva, infusion of malt, emulsion of almonds, &c., acquire this property as soon as, by the chemical action of oxygen, a disturbance in the equilibrium of the attraction of their elements has taken place, all doubt as to the true cause of these phenomena seems to disappear.' (We shall see later that in this Liebig is wrong, that meat, cheese, &c., cause putrefaction not from any inherent tendency to do so or from any state of decay, but because they introduce the necessary particles into the putrescible liquid.)

Liebig then goes on to say, with reference to the germ theory of putrefaction, that after the death of fungi and infusoria we observe the same putrefactive phenomena as after the death of a larger animal. These organisms, according to him, only appear at a late period of putrefaction, and therefore are not the cause of it, though no doubt by their vital actions they must hasten and modify the change.

And now let us pause in the history of this important subject, and methodise somewhat the views expressed. These may be divided into three sets. Firstly, we have that of Gay-Lussac, who attributes putrefactive and fermentative changes solely to the influence of oxygen in the first instance.

Then come the views of Caignard-Latour and Schwann, referring these changes to the entrance into the fluids of solid particles from without, which may be destroyed by heat. These authors go further, and ascribe the whole fermentative process to the growth of the organisms which are found in the fermenting liquids.

And, lastly, we have the view of Liebig, who looks on oxygen as in so far favouring fermentation that it causes eremacausis, the molecules undergoing this change being now capable of setting up putrefactive and other fermentative changes. The latter changes are therefore due to the presence of some substance itself undergoing change, and to this substance the term 'ferment' is applied. This ferment may be destroyed by heat.

It will be more convenient if for the present we class these views under two heads—the oxygen theory (Gay-Lussac's) on the one hand, and the particulate theory (Schwann's) on the other. At a later period we shall determine whether Liebig's or Schwann's is the more tenable view.

I have already mentioned the researches of Schulze, Schwann, Ure, and Helmholtz as tending more or less to upset the views of Gay-Lussac.

The next research of importance on this subject is that by Schroeder and Dusch.[1] Their aim was to see whether *filtration* of the air would be sufficient to prevent the fermentation of boiled fluids. Their apparatus was the following:—

A glass vessel containing the material to be tested (meat infusion, &c.,) was closed by a close-fitting cork, which was dipped into hot wax previous to its insertion. This cork had two holes in it which gave exit to two tubes bent outside to a right angle, these tubes being also firmly embedded in the cork; one tube was for the purpose of conducting air to the vessel, and the other to suck air out of it.

The conducting tube was connected by means of a short piece of vulcanised caoutchouc with a glass tube; the latter was again attached to a wider tube (1 inch in diameter and 20 inches long) by means of a similar cork to that in the bottle, and at the other end of this tube was a cork with a bit of tubing in it, called the open tube. The wide

[1] *Annalen der Chemie und Pharmacie*, 1854.



tube was loosely filled with cotton wool which had been previously heated for some time in a water bath.

The other tube—the suction tube—which in the interior of the flask reached almost to the level of the fluid, was connected by means of a vulcanised india-rubber tube with the upper tube of an ordinary gasometer, this latter tube being provided with a stop-cock. The gasometer was filled with water, and on opening the lower tube of this vessel the water flowed out and thus the gasometer acted as an aspirator. (See Fig. 2.)

Such was the apparatus employed. The fluid having been introduced into the flask, and all the connections having been

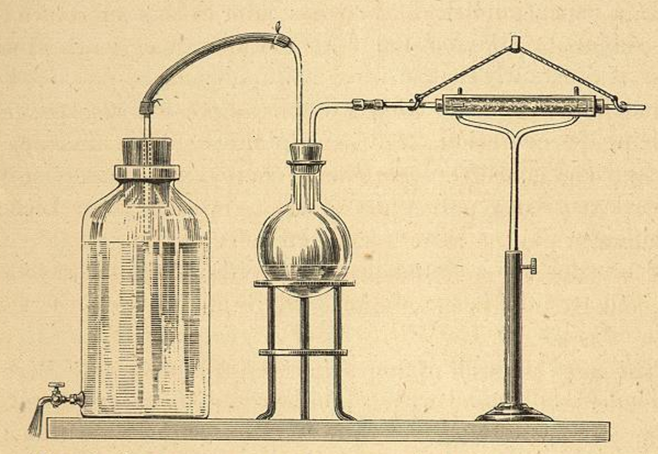

FIG. 2.—SCHROEDER AND DUSCH'S APPARATUS FOR SUPPLYING FILTERED AIR.

(The tube to the left ought to reach almost to the level of the liquid.)

ascertained to be air-tight, the cock of the aspirator was shut and the substance to be tested was boiled, till all the tubes as far as the cotton wool had been thoroughly heated; then, the joinings having been again examined, the aspirator was so arranged that water flowed out of it drop by drop, and thus sucked air slowly through the flask.

Meat, boiled in water and kept in a flask of this kind with constant change of air, was preserved for twenty-three days, and when tested at the end of that time was found to be quite unaltered, while a similar infusion left exposed to ordinary air had to be removed from the laboratory during the second week on