Subcutaneous surgery is another way in which the aseptic principle may be carried out. Here the wound is made under the skin and away from the air dust altogether. This method will be better understood when we come to trace the history of antiseptic surgery.

CHAPTER VIII.

THEORIES OF SPONTANEOUS GENERATION, HETEROGENESIS AND ABIOGENESIS.

Principles on which other methods of antiseptic surgery act. Organisms are always present in fermenting liquids: their significance. Theory of the origin of organisms independently of a parent. Theories of Needham and Buffon: Needham's proofs. Spallanzani's experiments: Needham's objections: Spallanzani's replies. Schulze's experiments. Schwann—Schroeder and Dusch—Schroeder—Doctrine of Heterogenesis. Pouchet's work: his method of testing the matter: proofs that the source of the organisms in infusions is neither the air, water, nor the putrescible substances: modes of repeating Schulze's and Schwann's experiments: examination of dust. Criticism of his results. Pasteur's experiments: results with ordinary fluids: introduction of dust into sterilised fluids: results with milk and alkaline fluids: the cause in the air which gives rise to the growth of organisms is particulate: Pasteur's cultivating fluid: estimate of Pasteur's work. Pouchet's reply: New experiments—Criticism of these.

Such are the methods by which that form of antiseptic surgery which aims at the total *exclusion* of septic ferments may be best carried out. But 'Antiseptic Surgery' in its broad sense includes another class of methods of treatment acting on a totally distinct principle, and interfering more or less perfectly with the occurrence of fermentations. These all act on the principle of *rendering inert the causes of putrefaction after their entrance into the wound, of offering obstacles, more or less complete to the fermentation which these particles would otherwise occasion.* In order to understand these methods, to see on what principles they act, to decide which are the best, and to carry them out with the greatest success, it is necessary to take up our discussion of the causes of putrefaction at the point which we have already reached, and to consider what is *the nature of the particles* which we found to be the causes of

fermentative changes, and how it is that they bring about these changes.

As is well known, micro-organisms of some form or other (bacteria, torulæ, &c.) are always present in fermenting liquids, and the view which is now almost universally held by scientific men is that these bodies are the initiators of the chemical change.

We have already seen that fermentation occurs only after the access of particles from the outer world, and it is asserted by the supporters of the germ theory of fermentative changes, that these particles are organisms or their spores, and that it is by the growth of these organisms in the fermentescible material that the latter undergoes alteration.

Some, however, assert that these organisms are only accidental accompaniments of the process of fermentation; in fact a few still maintain that they arise in fermenting substances from agglomeration of the molecules of that material, that in fact they are generated anew and are not necessarily derived from a parent. It is therefore necessary for us, before discussing the germ theory of fermentation, to consider what are the real facts with regard to this matter of abiogenesis.

The first views of which we must take notice, as being the first founded on experiment and observation apart from mere philosophical speculation, are those of Needham and Buffon, published in the middle of the eighteenth century.[1] Needham's

[1] It may be of interest to quote Needham's own words somewhat in detail. Referring to Spallanzani's criticisms of his work (*Nouvelles Recherches sur les Êtres microscopiques*, by Spallanzani, translated by M. l'Abbé Regley, 1769), he says (vol. i. p. 142): 'Il (Spallanzani) sait très-bien par toute la teneur de mes observations mieroscopiques que je ne donne aucune autre puissance à la matière que celle qui produit la pure vitalité dénuée de toute sensation, et qui dérive, comme son existence primitive, de la seule Divinité; que cette vitalité est un composé matériel de la force résistante et de la force expansive, dont les premiers principes ont été donnés à la matière par le Créateur au moment de la création: que tout corps, ou partie organisée, est une procession ou prolongation d'un corps organisé, soit végétal ou animal, qui doit nécessairement préexister, et dont la souche primitive sort immédiatement des mains de Dieu; que cette procession ou prolongation insensible, que doit donner ce germe nouveau, dont la petitesse est indéfinie, pour se conformer à toutes les circonstances possibles, se fait moyennant une espèce de réduction dirigée par les forces plastiques, et une concentration des parties spécifiques, qui tendent, en les atténuant, vers un point déterminé ou un certain foyer commun, de même à peu près que l'œil est au monde visible, un centre où les

theory was, that there is in matter a force charged with the formation and government of the organic world, which force he

rayons viennent s'arranger de toutes parts, sans confusion, dans le même ordre qu'ils reçoivent de l'harmonie préétablie de l'univers; que quant aux premiers principes de cette vitalité purement matérielle, il y a une matière indubitablement démontrée par des expériences constantes, très-atténuée, très-exaltée, éthérée selon Newton, électrique selon les idées présentes, très-élastique par sa nature intime, toujours prête à donner le branle à la matière brute et résistante, et qui pénètre substantiellement la masse entière; que par conséquent ces deux especes de matière, mêlées dans toutes les proportions possibles, peuvent fournir les témperaments nécessaires pour tout degré de vitalité quelconque, et pour tous les grands phénomènes ou changements physiques de l'univers en partant d'un seul principe; que cette vitalité, n'étant autre chose qu'un esprit très-subtil et très-actif, agissant dans une matière brute, tenace et ductile, pour former, selon les forces spécifiques de chaque corps vital, un nouveau système organisé, est très-différente, selon mes idées, du principe sensitif, qui ne peut être composé, et encore plus distinguée du principe intellectuel et spirituel, l'âme de l'homme.'

Further on (p. 150) he reiterates his view that these beings are distinct from the higher classes of animals which possess sensation. 'En général, toute substance quelconque, animale ou végétale, se décompose, selon moi, en êtres que j'appelle *vitaux* pour les distinguer des animaux parfaits à qui la Divinité a ajouté par surcroît les puissances purement sensitives, ou sensitives-intellectuelles.'

Again (p. 172), 'L'auteur (Spallanzani) croit que j'ai parlé de la force ordinaire végétante des plantes, par laquelle elles développent en feuilles, en branches et en racines. Il n'est rien de tout cela. Quand il s'agit de la production de ces corps organiques, je considère au contraire la plante dans un état de corruption comme plante: car c'est alors qu'elle perd absolument sa forme primitive et, qu'après avoir été dépouillée de ses sels, de ses huiles, et des autres principes constitutifs, ce qui reste devient une matière gélatineuse et toute filamenteuse qui végète par elle-même en branches vitales et se partage en corps ronds animés ou pousse au-dehors des globules mouvants.'

'Voilà en peu de mots le vrai tableau, voilà le raisonnement de M. de Buffon et le mien. Il y a certainement un principe de vitalité matériel distingué du principe sensitif, seul constitutif de la stricte animalité, qui se dispose organiquement, et qui, subordonné aux lois générales établies par la Divinité, végète dans les corps animaux qu'il forme comme dans les végétaux, en les animant à la façon ordinaire' (p. 166).

'Ce principe de vitalité est le *seul* principe d'économie et d'action dans les végétaux, et dans une certaine classe de ces êtres qui, paraissant sensitifs sans l'être, servent à lier ensemble le végétal et l'animal sensitif' (p. 166).

'Mais j'ai toujours reconnu comme nécessaire pour compléter le vrai animal, qui doit être sensitif, un principe de sensation, une âme qui n'est pas composée comme le système organique, et qui, quoique anéantie avec le corps selon le bon plaisir de son créateur, est néanmoins supérieure à la vitalité, et hors de toutes les puissances de la matière la plus exaltée.'

Buffon (*Histoire Naturelle*, vol. ii. p. 420, 1749) says: 'Tous les animaux

calls *force végétatrice*. He imagines that this force, by setting into motion all the particles of matter, excites in some of them a sort of vitality distinct from sensation, and produced by the union of two other forces, which he terms *force résistance* and *force expansive*.

The proofs on which Needham bases his views as to the spontaneous origin of these minute organisms are of three distinct kinds.

The first discussing the different phenomena furnished by different infusions, more especially the enormous variety of forms arising in them; and the second alluding to the behaviour of infusions after being subjected to heat, dependent as these arguments are on microscopical examination, need not be considered here, because the construction of the microscope was at that time so imperfect as to make it of little or no use for such observations.

The third, and indeed the only experiments which require to be noticed, are those in which infusions, contained in vessels hermetically sealed, are subjected to the action of heat for a prolonged period. In infusions treated in this way by Needham and boiled for many minutes organisms developed very readily.

Spallanzani [1] repeated these experiments, and he found that though some infusions could be sterilised after boiling for a short time, yet it was necessary to keep others at the boiling temperature for an hour or more before they would remain permanently sterile. Spallanzani's method was to heat his flasks, then to pour in the liquid, hermetically seal the flask, and place it in a water bath. The error in this method is probably that the impure fluid when poured into the flask, soiled the neck which he had previously purified by heat.

To these experiments Needham objected that Spallanzani had much enfeebled or perhaps destroyed the *force végétatrice* of the infusions by keeping them exposed to the action of heat for so long a period of time as an hour.

This objection was at once met by Spallanzani, who showed that organisms rapidly developed in these same infusions, if they were left exposed to the air after this prolonged boiling; and he truly says that, if the organisms only come from the fluid, and if the power which this possesses of generating these beings is destroyed by heat, they would remain absent whether the flasks were open or shut. He even went further and heated the vegetables very strongly before infusing them, but even in this case organisms developed in the fluids so prepared.

Needham, however, said that the small quantity of air remaining in the flasks was completely altered by the exhalations from the fluid and by the heat of the fire, and that thus the *force végétatrice* could not act. This objection cannot be said to have been in any way met by Spallanzani. In some cases, indeed, he succeeded in preventing the appearance of organisms by boiling the fluid from a half to two minutes, but in many cases minute organisms appeared. In order to prevent their occurrence in all instances, it was necessary to prolong the heat for at least three-quarters of an hour.

As an answer to Needham's last objection the experiments of Schulze [2] form a most important step in advance. The

se nourrissent de végétaux ou d'autres animaux, qui se nourrissent eux-mêmes de végétaux; il y a donc dans la nature une matière commune aux uns et aux autres qui sert à la nutrition et au développement de tout ce qui vit ou végète; cette matière ne peut opérer la nutrition et le développement qu'en s'assimilant à chaque partie du corps de l'animal ou du végétal, et en pénétrant intimement la forme de ces parties, que j'ai appelée le moule intérieur. Lorsque cette matière nutritive est plus abondante qu'il ne faut pour nourrir et développer le corps animal ou végétal, elle est renvoyée de toutes les parties du corps dans un ou dans plusieurs réservoirs sous la forme d'une liqueur; cette liqueur contient toutes les molécules analogues au corps de l'animal, et par conséquent tout ce qui est nécessaire à la reproduction d'un petit être entièrement semblable au premier. Ordinairement cette matière nutritive ne devient surabondante, dans le plus grand nombre des espèces d'animaux, que quand le corps a pris la plus grande partie de son accroissement, et c'est par cette raison que les animaux ne sont en état d'engendrer que dans ce temps.

'Lorsque cette matière nutritive et productive, qui est universellement répandue, a passé par le moule intérieur de l'animal ou du végétal, et qu'elle trouve une matrice convenable, elle produit un animal ou un végétal de même espèce; mais lorsqu'elle ne se trouve pas dans une matrice convenable, elle produit des êtres organisés différents des animaux et des végétaux, comme les corps mouvans et végétants que l'on voit dans les liqueurs séminales des animaux, dans les infusions des germes des plantes, &c.'

[1] *Opuscules de Physique animale et végétale*; traduits par Jean Senebier, Genève, 1777.

[2] See translation in *Microscopical Journal*, 1841.

following was the problem which he proposed and the method adopted to solve it.

Query: 'If the access of atmospheric air, light, and heat to substances in flasks included of itself all the conditions for the primary formation of animal or vegetable organisms? The difficulties to be overcome consist in the necessity of being assured first, that at the beginning of the experiments there was no animal germ capable of development present in the infusion, and secondly, that the air admitted contained nothing of the kind.'

His method of procedure is described by himself as follows:—

'I filled a glass flask half full of distilled water, in which I mixed various animal and vegetable substances. I then closed it with a

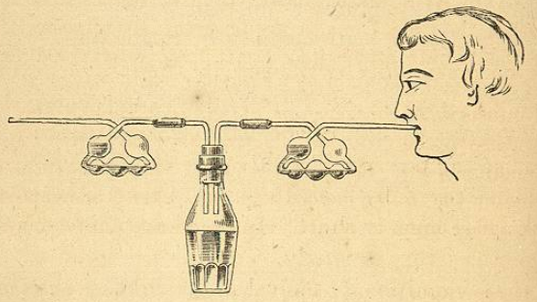

FIG. 58.—SCHULZE'S METHOD OF DEMONSTRATING THAT ORGANISMS ARE DERIVED FROM THE AIR AND DO NOT ORIGINATE SPONTANEOUSLY IN LIQUIDS.

good cork, through which I passed two glass tubes, bent at right angles, the whole being air-tight. It was next placed in a sand-bath and heated until the water boiled violently, and thus all parts had reached the temperature of 212° F.

'While the watery vapour was escaping by the glass tubes I fastened at each end an apparatus which chemists employ for collecting carbonic acid; that to the left was filled with concentrated sulphuric acid, and the other with a solution of potash. By means of the boiling heat everything living and all germs in the flask or in the tubes were destroyed, and all access was cut off by the sulphuric acid on the one side and by the potash on the other. I placed this easily moved apparatus before my window, where it was exposed to the action of light, and also, as I performed my experiments during

the summer, to that of heat. At the same time I placed near it an open vessel with the same substances that had been introduced into the flask, and also after having subjected them to the boiling temperature. In order now to renew constantly the air within the flask, I sucked with my mouth several times a day the open end of the apparatus filled with solution of potash; by which process the air entered my mouth from the flask through the caustic liquid, and the atmospheric air entered the flask from without through the sulphuric acid (Fig. 58). The air was of course not at all altered in its composition by passing through the sulphuric acid in the flask, but if sufficient time was allowed for the passage, all the portions of living matter or of matter capable of becoming animated, were taken up by the acid and destroyed. From May 28 till the beginning of August I continued uninterruptedly the renewal of the air in the flask, without being able, by the aid of the microscope (magnifying glass?), to perceive any living animal or vegetable substance, although during the whole of the time I made my observations almost daily on the edge of the liquid; and when at last I separated the different parts of the apparatus I could not find in the whole liquid the slightest trace of infusoria, of confervæ, or of mould. But all the three presented themselves in great abundance a few days after I had left the flask standing open. The vessel which I placed near the apparatus contained on the following day vibriones and monads, to which were soon added larger Polygastric Infusoria, and afterwards Rotatoria.'

By these experiments the fears entertained by Needham as to an alteration in the air contained in the flask being the cause of the sterility of the infusion, were completely set at rest; for here air, which had not been subjected to heat, and which was constantly changed, was present in the vessel in which no development occurred, while the second open vessel showed that the power of the liquid to nourish organisms had not been lost by boiling. It was therefore clear that in this instance the organisms which grew in the outer vessel came in some way or other from particles in the atmosphere, which could be destroyed by sulphuric acid. Whether or not both modes of origin might not exist, and whether the bodies falling into the fluid from the atmosphere were organisms or their spores, or merely albuminous matters which gave rise to organisms, was as yet in no way determined.

And the results of the experiments of Schwann, mentioned

before, leave us in the same position. In his case the heating of the air was substituted for Schulze's method of passing it through a chemical substance, but no further evidence was obtained. Advance was no doubt made by his results in that the objection which might have been urged by some against Schulze's experiments, viz., that particles of the sulphuric acid were carried over with the air, or that the air was in some way or other altered, are entirely removed,[1] while at the same time it was then known that heating air produced no alteration in the gases of the air. Schwann himself explained his results by supposing that the spores of infusoria and other smaller organisms are present in air, and are destroyed by heat; and he held that putrefaction and other fermentative changes are brought about by these organisms abstracting materials for their nutrition from the fluids in which they grow, and leaving the compounds thus broken up to form new combinations.

One most important fact he does mention, viz., that blood can be received into and preserved in a flask with certain precautions, without the development in it of any form of life.

Further evidence with regard to boiled substances was brought forward by Schroeder and Dusch, and later by Schroeder alone. Their method of experimentation by filtration of the air through cotton wool, and their results, have been already referred to (p. 12, *et seq.*), and it will be sufficient to add here that in those cases where putrefaction occurred, organisms were present, while in the flasks, in which no change took place, organisms were absent. By their method, meat, meat infusion, and malt were preserved after boiling without any appearance of organisms.

Difficulties were experienced with milk and yolk of egg, but these were finally overcome either by heating them to the temperature of 130° C., or by prolonged heat at 100° C. These experiments are of the greatest importance, as with the method

[1] This objection that the air is altered in passing through sulphuric acid is not urged by Pouchet, who indeed states that no alteration occurs, and that organisms can develop as readily when such air is admitted as in presence of ordinary air. Schulze's experiment also proves that the barrenness of the liquid was not due to the entrance of sulphuric acid into it, for the liquid became full of life after having been exposed for a few days to ordinary air.

employed no objections can be raised as to any alteration in composition of the air.

When, then, we look at Needham's two objections, which have been urged against experiments with boiled fluids, and when we compare with them the answers furnished by all observers, but more especially by Spallanzani to the first, and the progressively strong replies to the second by Schulze, Schwann, and Schroeder and Dusch, we must, I think, come to the conclusion that they have been completely met. Hence in order to retain the theory of spontaneous generation it became necessary for the heterogenists to change their ground. They had to admit that there were present in the air and on surrounding objects particles (not necessarily bacteria or their germs, though very probably so) which, falling on suitable soil, gave rise to the development of bacteria; but they still held that under certain circumstances heterogenesis may also occur, though possibly more rarely than propagation from a parent.

They attempted to support this view in two ways: firstly, by denying the accuracy of the former experiments, by pointing out that they do not always succeed, and that organisms develop in some materials, even after prolonged exposure to a high temperature; and secondly, by reference to the results of attempts to preserve unboiled fluids and tissues.

In 1859 there appeared the work of one of the most ardent supporters of the theory of spontaneous generation—Pouchet—and it is necessary for us to examine his views and facts somewhat in detail.[1]

Pouchet does not look on these organisms as originating from dead matter through the action of some mysterious force, as has been since advanced by some heterogenists. Their sources are, according to him: 'Des particules organiques, débris des anciennes générations d'animaux et de plantes, qui se trouvent combinées aux parties constituantes des minéraux. Selon cette doctrine ce ne sont donc pas des molécules minérales qui s'organisent, mais bien des particules organiques qui sont appelées à une nouvelle vie.' He further states that though he believes that it is the contact of different bodies which gives rise to the

[1] *Hétérogenie ou Traité de la Génération spontanée basé sur des nouvelles expériences.* Paris, 1859.

development of proto-organisms, yet he does not think that their origin is due to affinity alone—vital force must also come into play. This vital force owes its manifestation to certain unknown concomitant circumstances; thus fermentative or catalytic phenomena precede all spontaneous generation. In connection with these views he describes the development of ova in what he terms the proligerous pellicle, or scum on the surface of fermenting fluids. With regard to this he says: 'La génération primaire ne produit jamais un animal de toutes pièces, mais seulement elle engendre des ovules spontanés dans le milieu proligère absolument sous l'empire des mêmes forces qui façonnent des ovules dans le tissu de l'ovaire.'

The essentials for the production of new forms are, according to him, a putrescible body, water, and air, while heat, light, and electricity considerably favour the result. Having shown that the first three are essential, though they need not necessarily be present in large amount, he proceeds to state the problem in a very fallacious manner: 'Si l'on admet,' says he, 'que dans nos expériences la génération ne peut s'opérer qu'à l'aide de trois facteurs, et que c'est l'un d'eux seul qui récèle les germes des proto-organismes, il est évident que si l'on prend chacun de ces trois corps en particulier, sans s'inquiéter nullement alors des deux autres, et que l'on démontre successivement que ce n'est aucun d'eux qui contient ces germes, il faudra bien, en somme, reconnaître quand le fait aura été strictement établi pour chacun isolément, que ce n'est donc aucun de ces trois corps qui peut servir d'asile aux œufs ou aux séminales introuvables des êtres divers qu'on voit s'engendrer sous les yeux.'

He tests the question in the following manner: 1. With regard to the first point he says that it is evident that the putrescible material does not contain the germs of the proto-organisms since, even though it is charred previously to its employment, the water in which it is placed becomes rapidly filled with microzoaires and cryptogams.

Experiment.—10 grammes of any of the following seeds, maize, peas, beans or lentils, were placed in an iron spoon and completely charred; then the product was placed in a glass vessel containing 500 grammes of distilled water and covered with a bell jar. In twenty days the fluids were found to contain micro-organisms and cryptogams.

2. He next points out that it is not the water which contains the germs because, if one places organic substances in an artificial water, animalculæ and cryptogams still develop.

To show this an artificial water was obtained in the following manner:—'Into a large flask with two orifices, water and fragments of zinc are placed: one of the orifices transmits a tube terminating in a funnel by means of which sulphuric acid may be introduced into the flask; the other orifice is attached to a large horizontal tube filled with asbestos, which leads to a small tube drawn out at its extremity, and terminating close to the outside of a metal vessel filled with cold water. The sulphuric acid having been introduced, hydrogen gas is disengaged, and is lit at its exit from the tube. The flame being close to the metal vessel, moistens its walls with watery vapour, the result of the combination of the oxygen of the air with the hydrogen from the apparatus: and this vapour, being condensed, is caught in a platinum vessel. The apparatus having been maintained in this state for three days, 200 grammes of water were obtained, and were employed in the two following comparative experiments.'

Half of this water was boiled for a quarter of an hour, in order to kill the germs which might have fallen into it, although he does not consider that to be necessary. This water was then introduced into a vessel with 5 grammes of hay, which had been raised to a temperature of 200° C. The vessel was placed in a basin containing a little water, and the whole was covered with a small shade. In four days there was a granular pellicle and two species of Paramecia.

The other portion of distilled water was not boiled, and to it was added hay which had not been heated; the result was absolutely identical.

3. Lastly, Pouchet states that it is evidently not the atmosphere which disseminates the germs, since he has seen organisms appear in flasks containing only artificial air, or in flasks containing air which had been heated or which had passed through sulphuric acid.

He next takes up Schulze's experiment, and presents the following as a counter experiment and as a complete disproof of the former:—

A vessel of the capacity of one litre was half filled with water, to which 5 grammes of hay were added. The cork of the vessel was traversed by two tubes each bent at right angles, five centimetres above the place of exit; one, the afferent, did not descend into the interior