VI.—*Vegetable Tissues.*

Dr. Roberts has also experimented on the solid tissues of the turnip, potato, orange, and tomato, with similar success.

The following is his method for turnip :—

'A sterilised tube containing water was nicked with a file near the base of the capillary part, where the tube had a diameter of about two millimetres. A fresh oblong turnip was then fractured across, and the tube, snipped off at the nicked point, was quickly thrust into the substance of the turnip. A narrow cylinder of turnip about an inch long was thus forced into the column of water in the tube. The tube was then detached, and its end sealed with melted sealing-wax.' Of

14	tubes	thus charged	with turnip	10	were successful;
7	„	„	potatoes	4	„
8	„	„	orange	8	„
3	„	„	tomato	3	„

Ferments which induce changes after death are therefore not present in living vegetable tissues.

VII.—*Animal Tissues.*

Some years ago experiments were made by Billroth[1] and Tiegel[2] with the view of ascertaining whether the living tissues did or did not contain the causes of putrefaction. Having killed an animal, they opened its body rapidly, and removed with heated implements various portions of tissue such as liver, spleen, kidney, &c., and immediately dropped this into heated paraffin. They supposed that by this means any dust which fell on the tissue in its transit from the body to the flask would be destroyed by the hot paraffin, while this heat would not penetrate into and act on the interior of the tissue. At the same time the organs would be protected from air or dust by the paraffin.

They found that many portions of the body preserved in this way, notably the liver and spleen, underwent putrefaction rapidly, and they therefore concluded that the causes of this putrefaction were present in the living blood and tissues.

[1] *Coccobacteria septica.* [2] Virchow's *Archiv.* lx.

These experiments were repeated by Dr. Burdon-Sanderson, who obtained similar results and adopted the same views.

If, however, we look at the method, we shall find several objections to it. Thus, heated paraffin must be looked on as dry heat; it does not moisten solid particles in contact with it. Now it has been shown that dust, if kept dry, may be heated even to 300° F. without losing its power of causing fermentation. Further, paraffin solidifies at about 136° F., or even lower, and therefore paraffin, merely at its melting point, is not likely to be hot enough to destroy all septic particles. Further, during the cooling of the paraffin heavy particles of dust may fall into it and sink on to the tissue. Then, also, on the sides and bottom of the vessel is coarser dust, which likewise may not be destroyed.

But, again, paraffin is very apt to crack, and after cooling small cracks may occur which admit moisture and dust. To obviate this risk the paraffin has been covered with oil; but even here the oil becomes laden with dust and passes down through the cracks.

And, lastly, the knife, before dividing the tissue, compresses the vessels and forces the blood out of them, and thus, when these vessels are cut, air is sucked in, and this air carries its dust with it quite out of reach of the heat of the paraffin.

In December 1877 I commenced a series of experiments on this subject, and these have been continued at intervals since that time.

The first experiment was an imitation of those of Billroth and Tiegel (only it was performed antiseptically), and yielded conflicting results. Thus the liver and kidney putrefied, while the spleen, muscle, and mesentery remained unaltered.

This being the case, I determined to abandon this method entirely, and to see if some definite conclusion might not be arrived at in some other way. The following is a description of the method I have employed:—

A number of beakers, each provided with a cotton cap, were purified by heat, somewhat after Mr. Lister's method, and into each vessel about one-fourth of its volume of pure turnip infusion was introduced from one of the double-necked flasks (Fig 6, p. 19). This was done under the spray, and the cotton caps were then reapplied. These beakers

were placed in an incubator, and kept at a temperature of 98° F. for three or four days. At the end of that time the turnip infusion was clear and unaltered, and the flasks were therefore considered ready for use.

On January 6th, 1878, four beakers having been thus prepared, and six beakers containing melted paraffin being also at hand, a healthy rabbit was used for the following experiment.

The skin and hair of its abdomen having been thoroughly washed with 1–20 carbolic lotion, the animal was killed by a blow on the back of its neck, and the abdominal cavity was rapidly opened, under a fine spray of carbolic acid, with purified and heated instruments. Portions of its organs and tissues were rapidly cut out and introduced into the beakers, which were opened in the spray.

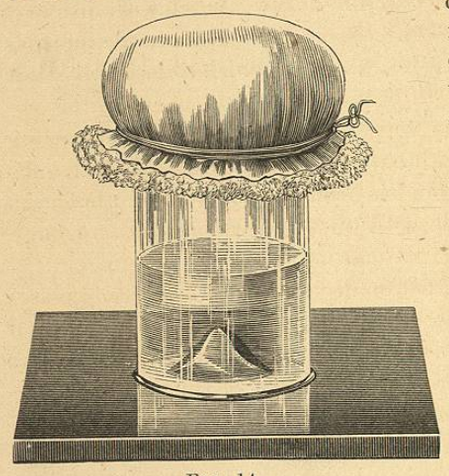

FIG. 14.

Into the four vessels containing the pure turnip infusion portions of liver, spleen, kidney, and muscle respectively were introduced, and the caps having been reapplied while the flasks were still in the spray, they were then placed in an incubator (see Fig. 14).

Into the six flasks containing melted paraffin portions of liver, kidney, spleen, muscle, mesentery, and vena cava, with its blood, were dropped also under the spray. The paraffin was left to solidify, and the vessels were then placed in the incubator.

All those portions of organs introduced into the turnip infusion remained permanently pure and free from putrefaction.[1]

Of the paraffin beakers, two (muscle and vena cava) remained without change; while the other four (liver, spleen, kidney, and mesentery) putrefied.

In this experiment we have in the first case a series of

[1] On December 24, 1880, I killed a rabbit and preserved its organs in the way described here. Fig. 34, Plate V., is drawn from a specimen taken from the beaker containing the spleen, and stained. It will be seen that no organisms whatever are present.

beakers heated so as to destroy the activity of the dust adhering to them, and that this was effectually done was proved by the fact that the turnip infusion introduced into them underwent no change, although, as has been amply shown in the foregoing experiments, had ordinary unheated dust been present, this infusion would have undergone fermentation.

Further, the portions of the tissue are transferred from the body to the beaker without the possibility of acquiring living dust, for, as we have seen before, a spray of carbolic acid in an ordinary atmosphere is able to destroy the fermenting power of the dust. Such being the case, if the tissue, taken with all precautions undergo putrefaction, it is possible that the causes of this fermentation were present in it while in the living body—the degree of probability depending of course in great measure on the known skill of the experimenter. But if no change occurs, it is proof positive that there were no causes of change present in the body. In other words, as these unboiled tissues remained unaltered, it is quite certain that they have no *inherent* tendency to undergo fermentation even when freely exposed to air.

I used the turnip infusion partly because I wished to know whether the beakers had been thoroughly purified, and partly in order to keep the tissues moist, for I had found in a former experiment that they dried too rapidly in the open-mouthed vessel if no fluid were present. Since that time I have used cucumber fluid, as being more putrescible.

Further, by the use of these infusions the conditions favouring fermentation are greater, for we have here a boiled highly putrescible infusion of turnip, and an unboiled, if possible still more putrescible, infusion of meat, as well as the meat itself. It were hardly possible to provide more favourable conditions for fermentation. Nevertheless no change occurred.

I may here point out the light thrown by these experiments on the cause of the want of success in the paraffin experiments. In the first attempt which I made with the paraffin any of the supposed causes of failure might have been in operation, but in the experiment just narrated the entrance of air laden with septic dust into the blood-vessels is excluded because the operation was done in a spray of carbolic acid. Therefore the failure in

the four vessels must have been due to dust in the paraffin, or to cracking of this after solidification.

But, it may be said, the absence of putrefaction in the beakers was due to the action of the carbolic acid on the tissue. This, however, is not the case, for the following reasons:—

In a preliminary experiment I touched the outside of the flask (which was of course covered with impure dust) with one of the portions of the tissue, and afterwards introduced this piece into the flask, and in it putrefaction occurred rapidly. Again, the fact that four paraffin flasks went wrong (the organs being there also subjected to the action of the spray) shows that this had no influence. Again, when the gall-bladder is wounded fermentation often occurs. This latter fact is illustrated by the following experiment:—

A medium-sized rabbit was killed by a blow on the nape of the neck. The abdomen had been washed beforehand with 1–20 carbolic acid lotion, and was now rapidly opened under the spray. Into seven beakers containing pure cucumber infusion, two pieces of liver, one piece of kidney, one piece of spleen, one of muscle, and one of mesentery were introduced. In cutting out the liver the gall-bladder was injured.

Four weeks later, five beakers were unaltered, the two which had fermented being those containing the pieces of liver, which indeed had undergone fermentation within twenty-four hours.

I have since met with several similar instances.

Further, if putrid matter be injected into the jugular vein of the animal a few minutes before death, all the tissues removed and preserved in the manner described undergo putrefaction.

I have repeated these experiments many times with like results,[1] and I therefore conclude that the *tissues* of the healthy

[1] On two occasions I have found that the apparently healthy living tissues, preserved by the method before described, underwent fermentation and organisms developed in them. In one case the kidney alone of all the organs taken, and in another both kidney and liver, underwent fermentation with development of organisms, and as I was very careful in performing the experiments, I do not think that this could have occurred from any error in experimentation, and therefore I conclude that the causes of fermentation (micro-organisms, as we shall afterwards see) were present in the healthy circulating blood. That an organism may be present in an active state in the circulating blood need not be a matter of surprise, and need not therefore lead us to the conclusion that they are always or even generally there, especially as one single organism would be sufficient to account for the result in each of these instances. It is indeed surprising that organisms which must now and then enter the blood are so rapidly and surely destroyed.

living body, like the fluids, contain no ferment capable of causing putrefaction after death, and remain pure in flasks so long as the dust of the atmosphere is excluded. (In some instances the heart with its contained blood was also removed, and remained, like the other tissues, unaltered. Rabbits and cats were the animals used for the experiments.)

Somewhat similar experiments were published in 1878 by Chiene and Ewart, and they yielded similar results.[1]

Quite recently,[2] Rosenbach mentioned experiments on this subject performed by Meissner. Meissner was able to preserve the internal organs of cats and rabbits in contact with boiled water and pure air, for two to three years, without the occurrence of any putrefactive change. He was also successful in preserving the blood of mammalia, human urine, and goat's milk. The experiments were done with strict aseptic precautions, and led him to conclusions similar to the above.

Such, then, are the chief facts at present known with regard to boiled and unboiled fluids and tissues. We shall add much to them, and to the support which they give to the views here expressed, when we come to consider more minutely what is the nature of the particles which cause putrefaction.

On reviewing the mass of evidence before us we have it distinctly shown that boiled fluids and tissues have no inherent tendency to undergo fermentative changes; that oxygen, whether pure, nascent, or mixed with nitrogen in the proportions present in air, cannot cause fermentation, if only the air be previously passed through such a liquid as sulphuric acid, be heated strongly, be filtered through cotton wool, be made to enter very slowly into the flask containing the fluid or allowed to deposit its dust by gravitation, or be previously acted on by carbolic acid.

[1] *Journal of Anatomy and Physiology.*

[2] *Deutsche Zeitschrift für Chirurgie*, xiii. 344.

Thus the material in the air which causes putrefaction is not a gas, for that would be continuous, and would not be removable by filtration or by rest; but it is something discontinuous, something heavier than air, something particulate. These particles may be deprived of their power of causing fermentation by the action of chemical substances, such as sulphuric and carbolic acids, and also by being subjected to a high temperature. As they are completely destroyed by heat (as shown by Tyndall), they are probably of an organic nature.

And it is not that by boiling these fluids an inherent tendency to ferment has been destroyed, for, as we have seen, they possess no such inherent tendency. For not only do unboiled fluids and tissues outside the body fail to putrefy when protected carefully from dust—they also undergo no change, as indeed necessarily follows from the foregoing, when confined in natural or artificial cavities in the living body. Who is not acquainted with the behaviour of blood when extravasated into the tissues or cavities of the living body so long as it is not exposed to the outer world? We all know what a large amount of effused blood may be present about the ends of a fractured bone without decomposition occurring in it, and the same is the case in the hemorrhages into joints in hemophilia, hemorrhages within the skull, &c. And we also know what frequently happens if we cut into any of these extravasations and admit dust-laden air into them. The blood which we found odourless, and it may be clotted, may become in a few hours a foul-smelling liquid; it has, in fact, putrefied, just as it may do when kept in a flask without exclusion of dust.

And just as in the case of blood, so with other fluids. Hydrocele and serous effusions remain unaltered so long as they are kept from the dust. Examine the pus from a chronic abscess, and even though that abscess be connected with carious bone, it will be found to be odourless and bland, and if carefully received into pure flasks, will, just as in the case of blood, remain odourless and apparently unchanged for an indefinite length of time. (I shall give later on the explanation of the cases where the pus of acute abscesses, when let out, is found to have a foul smell, as is sometimes the case in acute necrosis.)

And not only is this the case with fluids, it is also the case with tissues in the living body. In a fracture many portions of the tissue are cut off from their vascular supply, or killed by the violence causing the injury, and yet they do not decompose; they are not separated as sloughs—they disappear by absorption. Yet if the same injury be not subcutaneous and the injured parts be exposed to ordinary air, they putrefy, and come away in a few days as sloughs.

So in infarcts in internal organs, the tissue in the region of the infarct dies, but does not putrefy—does not slough; while when death of the integuments occurs, putrefaction and sloughing follow, for here the dead tissue is exposed to the dust of the atmosphere.

Similarly, in the case of wounds, when a piece of skin is cut away and an open sore is left, the blood and serum which collect in that sore ferment, in all probability putrefy, because the air admitted to them was not heated air, not filtered air, was air which had not been acted on by suitable chemical substances.

The causes of fermentation are therefore solid particles, probably of an organic nature, which are present in varying quantities in the surrounding air, and which are deposited as dust on all surrounding objects.

It is thus evident that in order to prevent putrefaction it is only necessary to prevent the access of these particles, or, if this cannot be done, to destroy their fermenting power in some way or other before they reach the wounds—as, for instance, by the use of carbolic acid.

It is on this principle that *Aseptic Surgery*,[1] as introduced by Mr. Lister, is based.

[1] The term 'aseptic' is the best to indicate this form of antiseptic surgery, because, as we shall see, there are many different forms of treatment which come under the term 'antiseptic,' while this is the only one which can truly bear the name 'aseptic.' In other words, there are many methods by which the occurrence of putrefaction is more or less interfered with, but they all act on a more or less imperfect principle, with the exception of that introduced by Mr. Lister, which, founded on a true principle, attains the ideal of results—viz. a complete absence of putrefaction—an asepsis. His method, then, is best designated by the term expressing its result—Aseptic.