

**TRANSCRIPTION OF HANDWRITTEN TEXT BY SIR WILLIAM
WATSON CHEYNE, CONTAINED IN TWO VOLUMES OF HARDBACK
NOTEBOOK WITH SLIGHTLY TORN COVERS. ANY NOTES OF MY
OWN ARE MARKED THROUGHOUT IN [...] AND INITIALED JM.
JANE MACK, FETLAR MUSEUM TRUST, JULY-DECEMBER 2003.**

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This handwritten original contains Cheyne's original notes, and the text is transcribed here with his notes, corrections and amendments.

On inside front cover:

To Dr. Storer
182 Boylston Street
Boston
Mass.
U.S.

On facing page:

Antiseptic Treatment. What are its essential details? How are they best carried out in practical form?

By Truth, our guide.

Boylston Medical Prize Essay, Harvard University.
By W. Watson Cheyne.

[The text - page numbers are marked in red ink in the top right hand corner of each even-numbered page only. Headings and other notes are marked on odd-numbered pages in red ink]

Preface

In the following essay I have attempted as far as possible to adhere to the lines indicated by the committee. It was however absolutely necessary, in order to explain the views which I hold with regard to antiseptic treatment, for me to enter at length into the subject of the causes of putrefaction, to obtain if possible some principles to guide us in the attempts to prevent it. At the same time I have tried to avoid all unnecessary discussion & I have purposely refrained from entering into the history of antiseptic surgery or into the statistical details of the results already obtained.

I do not mean to imply by this essay that attention to the antiseptic details is the only principle to guide us in the treatment of wounds. On the contrary the great principle is Rest. Rest from mechanical effects such as tension, movement &c. and Rest from chemical disturbances such as the products of putrefaction or other chemical substances used in the treatment of the cases. Of these no doubt the antiseptic details are the most important for by strict attention to them septicæmia & pyæmia may be avoided but without attention to the other means of obtaining physiological rest the best results cannot be obtained. As however merely the antiseptic part of the treatment of wounds was demanded here I have directed my main attention to that subject.

Truth, our guide.

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Antiseptic Surgery = surgery directed against the causes of putrefaction

Necessary therefore to enquire what are these causes.

Definition of Putrefaction and fermentation

Two classes of ferments are generally recognised one acting by catalysis

Not having the power of self multiplication

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The term, “septic”, so much used in surgery at the present day, is derived from the Greek word σηπτικός which means something that causes putrefaction, the verb σηπῶ being to cause to rot, to make putrid. An “Antiseptic” is therefore something which acts on the causes of putrefaction, and “Antiseptic Surgery” is surgery directed not against the effects of putrefaction but against its causes. In dealing then with the subject of Antiseptic Surgery (in order then to determine what are the best methods of carrying out Antiseptic Surgery) we must first enquire what is putrefaction & how it is brought about.

At the present day Putrefaction is generally held to be a form of fermentation accompanied by the development [sic] of offensive odours: and fermentation may be defined to be “ a new arrangement of the elements of an organic compound (often with the assimilation of the elements of water) & the consequent formation of new products” (Fownes Chemistry)

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 most notable are Hydrocyanic acid & oil of bitter almonds. This de-

composition of amygdalin is however not effected by combination with Emulsin for the latter remains unchanged though its presence is necessary for the chemical action. Similar facts are known with regard to the pepsin of the gastric juice, the ptyalin of the saliva, the pancreatic ferment &c. But although these ferments undergo little or no change (they do gradually diminish in amount and are not unlimited in their action) yet nevertheless it has been clearly proved that they have not the power of self multiplication.

The other “vital” ferments having this power

Contrast between the two varieties

Another class of ferments however exist which possess this power in a very marked 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 & soon bubbles appear in this solution, fermentation has set in and now goes on slowly till the sugar is completely decomposed. If we compare this process with the former we see two marked points of difference; in the first place in the former the process of change is rapid & more or less instantaneous; in the latter it progresses slowly & steadily, & requires a much longer period for its completion. In the former there is no increase in quantity of the ferment; in the latter the increase is very marked & 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.

Points in which they correspond

See German insert on subject

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 the vital action of living cells; & it is quite possible that the yeast plant may, in the latter case, act in the same way as the salivary cells, by excreting a ferment which produces the change in the sugar, 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 & cannot live apart from the organism, hence the ptyalin, introduced into starch[,] does not increase in amount. On the other hand the yeast plant is an independent organism & grows in the fermentescible fluid, & it is to the growth & multiplication of these living cells & not to an increase in quantity of a chemical ferment that the multiplication of the fermenting power is due.

Putrefactive fermentation is a “vital” fermentation

In the putrefaction of discharges in wounds we have to deal with a ferment belonging to the class of the alcoholic ferments – with a ferment capable of multiplication & acting slowly & steadily, not

It is therefore necessary to enquire into the origins & history of this class of Ferments

Lavoisier directed his attention to the changes which fermenting fluids undergo

Fabroui's views

suddenly. We must therefore enquire a little more fully into the nature of this ferment, into its origin & its history in order to obtain some principles to guide us in attempting to prevent its action.

In reviewing the history of this subject the first research of any consequence which is necessary for us to consider is that of Gay Lussac (Annales de Chimie vol.76. 1810), although previous to the publication of this essay attempts had been made by Lavoisier, Fabroui & 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 (Elements de Chimie Vol.I. 2nd Edition). He does not attempt to assign a definite cause for fermentation.

Fabroui (Annales de Chimie vol.31, 1799), 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 & as soon as these two substances come into

contact effervescence or fermentation commences just as occurs in every other chemical process, as for instance when an acid & a carbonate are mixed in the same vessel.” As we have seen he identifies the ferment of grape juice with gluten.

Thenard's views

Some years later but ignorant of M. Fabroui's view Thenard published a research on alcoholic fermentation (Annales de Chimie vol.46. 1803) in which he showed that Gluten had no effect whatever on sugar in the way of causing fermentation. He however observed that during the process of fermentation a deposit occurred which had the power of inducing fermentation in a fresh saccharine liquid. This substance was apparently the same in a great variety of liquids of different chemical composition & it presented similar characters 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 & became deposited as a result of the changes which occurred. He however inclines towards the latter view.

Gay Lussac

Gay Lussac was led to make his investigations by studying the procedure of M. Appert for preserving vegetable & animal substances (Appert, The art of preserving animal & vegetable substances). Appert's method consisted in placing the materials to be preserved

Appert's method of preservation

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 & 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 Appert's conserves, when exposed to air fermented

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, & more especially if the substances were decanted into other vessels, their contents underwent fermentative changes.

First experiment

To ascertain why this occurred he took a flask of grape juice which had been preserved for a year unaltered & which was accordingly quite limpid. Having opened the flask he poured its contents into another vessel which he closed very accurately & kept at the temp. of 15° - 30° C. Eight days later the juice had lost its transparency, fermentation had become established & it soon became an alcoholic fluid. A second vessel containing grape juice was kept at the same temperature & in the same place but unopened & remained pure. This latter flask, the neck of which had been drawn out, was now taken &, a deep notch having been made in its neck with a file,

Gay Lussac's conclusion

By reboiling the substance could be again preserved

During this boiling the substance loses its transparency & a deposit takes place

its neck was plunged into mercury & then broken off. A portion of the contents were then introduced into a bell jar containing no oxygen & a second portion into one containing a small quantity of that gas. The first remained without change for 40 days while the second underwent fermentation very rapidly. In the latter flask all the oxygen was absorbed but much more carbonic acid in proportion was produced. Gay Lussac therefore concluded that though 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 came to the same 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.

It is of interest to observe that he was able to preserve animal substances as also urine milk &c. exposed to the air, by heating them at first every morning & subsequently every second morning.

Gay Lussac concludes from his experiments,

Gay Lussac's views

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 & to make the oxygen present unite to form some substance which is not a ferment; that the product of this union of oxygen with the substances heated is the deposit 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 reactions.

Caignard Latour discovered the yeast plant

Passing now over a period of some years we come to the views of Caignard Latour made known in papers presented to the Academie des Sciences during 1835-36-37 (see Annales de Chimie et de Physique t.68 2^e Serie 1838). On examining fermenting grape juice he found (as indeed had been imperfectly observed before by Leuwenhoeck & Desmazières) that it contained numerous globular bodies which he considered of vegetable nature & which he found to possess the power of reproduction partly by budding & partly, as he supposed, by contracting and liberating numerous spores. From several facts, among others from finding that in juices not undergoing alcoholic fermentation these

Views of Caignard Latour

were absent while they were present where that recurred he concluded that those bodies were the cause of the fermentation. He further found that the deposit of which M. Thenard spoke & which he had stated to be the ferment, was composed entirely of these bodies.

Schwann announced similar views.

Similar views were announced almost simultaneously by Schwann (Poggendorffs Annalen vol 41 – 1837) & to him rather than to Caignard Latour must be given the credit of having furnished the first real proof of these views.

He showed that heated air might be brought in contact with Appert's preserves without causing fermentation

He 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 ultimately adopted by him.

Details of his experiment

“Into a 3oz. vessel a small piece of meat was introduced & then water was added so that the whole occupied about $\frac{1}{4}$ th 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 & its orifice dipped into a small beaker containing mercury covered with a layer of oil. The other tube ran at first horizontally & then directly downwards for an inch & a half. Thus 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 whole 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 & the steam was made to issue from the two tubes till the mercury & oil became so hot that they no longer condensed this steam. (In order that no organisms might develop [sic] in the water which remained between the oil & 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 & the heat was continued till the tube began to soften. The drops of water condensing in the cooler parts of the tube were dispelled by another lamp. After boiling had continued for a quarter of an hour it was stopped & 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 & the portion of the tube between the spiral & the end, containing, as it did, unheated air was heated. That being done the spirit lamp was completely removed.

This flask thus contained only boiled meat infusion & 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 & 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.

General results

In this way Schwann succeeded in preserving meat & other substances for 6 weeks at a temperature of 14° - 20° R. without any putrefaction and without the appearance of organisms in them; while the same fluids when exposed to ordinary air underwent putrefactive changes in a few days.

It was thus evident that there was something present in the air, other than the gases of the air, which had the power of bringing about fermentative changes in fluids, & 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.

Further experiments

A solution of cane sugar having been mixed with yeast, four flasks were quite filled with this mixture & then corked. These flasks were then placed in boiling water for an equal length of time (10 minutes each). They were then inverted over mercury

& air was introduced so as to displace $\frac{1}{3}^d$ to $\frac{1}{4}^{\text{th}}$ of the fluid. The flasks were then corked under mercury & kept at a temperature of 10° to 14° R. In two flasks the air thus introduced had been previously heated, in the other two it had not been so treated. In 4 to 6 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 3 months.

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

It is but fair to refer here to the experiments published in 1836 by Franz Schulze on spontaneous generation. These will be referred to later on. They are however of interest as Schulze anticipated Schwann in the principle of admitting air, previously acted on chemically, to Appert's preserves.

Schwann's experiments were repeated & confirmed by Ure in 1840 (Journal für praktische Chemie Vol 19)

Schultze [sic] experiments by passing air through H_2SO_4

Ure repeated & confirmed Schwann

Likewise Helmholtz
Helmholtz showed that nascent oxygen did not cause fermentation

& by Helmholtz in 1843 (Müllers Archiv 1843). The latter author, in order to test further the oxygen view, prepared an infusion in the usual manner in a vessel into which platinum electrodes were fixed. After the infusion had remained unaltered for some time a stream of electricity was sent through the liquid, decomposing the water. But even this oxygen in its nascent & therefore in its most active state was unable to produce any fermentation in the fluid.

Liebig's views

In the meantime however Liebig had stepped forward as the opponent of the views advanced by Caignard-Latour & by Schwann. He proposed a theory of a totally different nature. (Annales de Chimie et de Physique 2^e Serie vol 71 – 1839).

After pointing out how organic molecules have a tendency to alter their constitution, to break up & rearrange themselves, he approaches the question of putrefaction & 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'alteration qu'il éprouve lui-même.”

He compares this sort of action to combustion

& cites several well known instances of this kind, such as the decomposition of nitric acid by an alloy of platinum & silver while this does not take place with the platinum alone, & also the decomposition of peroxide of manganese by oxide of silver &c in water containing oxygen.

Eremacausis

leading to Putrefaction

Ferment – definition & mode of action

He includes under the term éremacausis (combustion by degrees) the alterations which organic substances undergo at ordinary temperatures & as the result of the presence of oxygen. When oxygen is excluded, putrefaction occurs. This 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 & 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 putrefaction. This latter substance is therefore termed a ferment. This ferment is a nitrogenous substance undergoing putrefaction & 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 the ferment which is active & this does not

*Thenard 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 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 in fermentation & in his latest works Liebig admits this.

act by direct contact, but in consequence of a decomposition which it undergoes itself. 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* The ferment is therefore 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) & therefore a sufficient quantity must be present in order that its decomposition may not be completed till that of the sugar is ended. No special substance is, according to this view, required in order to act as a ferment, but merely some material to act as the constant exciter of an action in the fermenting substance (this is quite erroneous because putrefying fluids & tissues added to sugary solutions do not convert the sugar into alcohol. This was latterly admitted by Liebig who was compelled to allow some relation between the yeast plant & the alcoholic fermentation which connection however he attributed to the effect propagated from the dead & dying – not the living cells)

Liebig sums up as follows.

Organic compounds present two kinds of opposite

Liebig's conclusions

& definite phenomena:

1. They give rise to bodies endowed with new properties in that the elements of several molecules of a more simple compound unite 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 its elements. This equilibrium is destroyed 1. by heat. 2. by contact with a different body & 3. 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 & composition (eremacausis) which is transferred or communicated to the urea & the hippuric acid; the urea is resolved into carbonic acid and ammonia; the hippuric acid disappears & 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

Meat, cheese &c. all cause putrefaction not from any inherent tendency to do so but because they introduce the necessary particles into the putrescible liquid.

Liebig criticises the germ theory

General review of the facts stated

saliva, infusion of malt, emulsion of almonds &c acquire this property, as soon as, by the chemical action of oxygen a disturbance in the state of equilibrium in the attraction of their elements has taken place, all doubt as to the true cause of these phenomena seems to disappear.” *

Liebig then goes on to say, with reference to the germ theory of putrefaction, that after the death of fungi & infusoria we observe the same putrefactive phenomena as after the death of a large animal. These organisms only appear at a late period of putrefaction (quite erroneous) therefore are not the cause of it though no doubt by their vital process they much hasten & modify the change.

And now let us pause in the history of this important subject & methodize somewhat the views expressed. These may be divided into 3 sets.

Firstly we have that of Gay Lussac who attributes putrefactive & fermentative changes solely to the influence of oxygen in the first instance.

Then comes [sic] the views of Caignard-Latour & Schwann ascribing these changes to solid particles entering the fluids from without, particles which may be destroyed by heat. These authors go further & ascribe the whole fermentative process to the growth of the organisms which are found in these fermenting

liquors. And then we have the view of Liebig who looks on oxygen as so far favouring fermentation in that it produces eremacausis, the molecules undergoing this change being now capable of setting up putrefactive changes. The latter changes are due to the presence of a ferment itself undergoing putrefaction. This ferment may be destroyed by heat & in so far is explained the results of Schwann's experiment of heating the necks of the flasks.

It will now be more convenient if we for the present consider these views as consisting of two groups – that of Gay Lussac on the one hand & that of Schwann & Liebig on the other, & at a later period we shall determine whether Liebig's or Schwann's is the more tenable theory.

I have already mentioned the researches of Schulze, Schwann, Ure & 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 & Dusch (*Annalen der Chemie & Pharmacie* 1854). Their aim was to see whether filtration of the air would be sufficient to prevent the putrefaction of boiled fluids. Their apparatus was the following; a glass vessel containing the material to be tested

Consider the views on this subject for the present as consisting of 2 varieties

Schroeder & Dusch filter the air

Their method

“(meat infusion &c) was corked by a cork closing the vessel completely & 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 which tubes were also firmly embedded in the cork, one being distorted to form a tube conducting air to the vessel & the other to suck air out of the vessel.” The conducting tube was connected by means of a short tube of vulcanised caoutchouc with a glass tube; the latter was again attached to a wide tube (1 in. in diameter & 20 in. long) by means of a similar cork to that in the bottle & at the other end of this tube was a cork with a bit of tubing in it called the open tube. The wide 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 &, on opening the lower tube of this vessel the water flowed out & thus the gasometer acted as an aspirator.

Such was the apparatus employed. Everything having been arranged & all the connections having been ascertained to be airtight, the cock of the aspirator was shut & the

substance to be tested was boiled till all the tubes as far as the cotton wool had been thoroughly heated, then the joining having been again tested the aspirator was so arranged that water flowed out of it in drops & thus sucked air slowly through the flask.

Experiment with meat

Meat boiled in water & kept with constant change of air was preserved for 23 days & when tested at the end of that time was found to be completely unaltered, while a similar infusion left exposed to ordinary air had to be removed from the laboratory during the second week on account of its intolerable stench. This experiment was repeated several times with similar results.

with fresh sweet malt

Schroeder & Dusch preserved in this manner fresh sweet malt containing hops. Twenty three days after such a fluid was prepared, while it still remained unaltered, the cotton was removed & the sucking in of the air – now unfiltered – was still continued. The fluid was muddy & covered with fungi & had undergone fermentation in a week.

with milk

They were however unable to obtain like results with milk or with meat heated without the addition of water, these substances invariably undergoing putrefaction.

Schroeder's later work

In a paper published 5 years later Schroeder returned to this subject (Annalen der Chemie und Pharmacie Bd.109. 1859)

Having found that white of egg mixed with water if constantly shaken while boiling could be preserved for an

Ozone has no power to cause fermentations

various substances tried

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indefinite time he tried whether ozone had any power in inducing fermentation. Dilute sulphuric acid was decomposed by electricity & the ozone thus generated was conducted into a vessel containing pure white of egg. The latter was kept thus for 38 days & was still at the end of that time unaltered.

He was still unable to succeed with milk or yolk of egg though the latter if previously heated to 160°C in an oil bath generally remained unchanged & the milk also sometimes kept pure.

The special constituents of milk could be easily preserved as Casein precipitated with acetic acid & washed with water. So the whey left on this precipitation - when this whey was boiled a deposit occurred & this was readily kept pure & the whey still remaining did not ferment when preserved with the precautions mentioned.

He also tried other substances such as blood, urine, starch &c. & succeeded with these.

The only ones which failed were milk, yolk of egg, meat & occasionally meat infusion.

As the result of these contradictory experiments he comes to the conclusion that there are two ways in which fermentation may be caused; firstly by some solid particle which can be stopped by cotton wool & secondly by oxygen gas (in the case

Conclusions.

Schroeder's views (later research)

He succeeds with yolk of egg

with meat & milk

Appert's method for preserving milk

of milk, yolk of egg &c.

Two years later there appeared another paper by Schroeder referring to these substances which he had previously failed to preserve & in this research he has recourse to the use of higher temperatures than formerly (Annalen der Chemie & Pharmacie vol.117. 1861)

Yolk of egg after being heated for ½ hour in a closed glass vessel at t. of 130° was placed in a flask the neck of which was stuffed, when hot, with cotton wool & boiled with a little water. This remained for 70 days unchanged.

He succeeded in like manner with meat & milk, & in the case of the latter he found that prolonged boiling at 100° was sufficient.

From these facts he gives up the formerly expressed view as to spontaneous decomposition under the influence of oxygen & concludes that in these fluids spores were present which could resist a boiling temperature. He further considers that these spores were present originally in the milk & were not introduced from the air, because he finds that milk which has not been boiled at all putrefies sooner than pure boiled milk exposed to the air.

It may be interesting to mention here that similar difficulties were experienced by Appert in his attempts to preserve milk. He however succeeded

by the following method. “Condense the milk to $\frac{2}{3}$ ^{ds} of its volume, strain it, then put it in the bottle, seal, & boil in a waterbath for two hours. In order to prevent the cream separating, he found it well to add yolk of egg. This did not increase the difficulty in preserving it.

Still further evidence disproving the gaseous theory is furnished by Pasteur (Annales des Sciences Naturelles Serie IV. T. XVI 1861 Zoologie).

Pasteur repeated Schwann’s experiments & was successful with most fluids but for a time he failed in the case of milk. He however succeeded when he boiled the milk under pressure at 110°C. for one or two minutes & then allowed heated air to come in contact with it. Such milk remains unaltered for an indefinite length of time but it readily decomposes if unheated dust be introduced into it in the manner to be afterwards described (under spontaneous generation).

The most striking of Pasteur’s experiments is that of the flask with the bent neck. A flask containing, say, milk is heated so as to render its contents pure. Its neck is drawn out & bent so as to be very long & tortuous & then after the boiling the lamp is simply withdrawn the neck being neither heated sealed nor plugged. Nevertheless the fluid does not undergo any change.

Pasteur’s experiments

Succeeded with milk

Experiment with flasks with open bent necks

If, on the other hand, the neck of this flask be sealed during ebullition, a more or less perfect vacuum being thus produced, & if after cooling this neck be broken air rushes violently into the flask carrying with it its dust & causes putrefactive changes in the fluid. In the same way if one of the flasks with open necks, the contents of which here remained for some time pure, have the neck broken off short, the fluid in its interior rapidly undergoes putrefaction.

Thus in the case of the flask with the long neck the dust is caught in the angles & in the first inrush of air these angles are filled with water which filters the air. Pasteur thought [*thinks* written above in pencil] that part of the air entered the vessel instantly but that the fluid & the walls of the flask are at that time so hot that any living particles present are immediately destroyed.

These experiments have been repeated by several observers with success & Mr. Lister has at present in his possession a flask of this kind containing urine which is now 12 years old but which still remains unaltered & as limpid as on the day when it was passed.

In a lecture on Haze & Dust (Nature Jan^r 27th 1870) Prof. Tyndall showed that if no dust were present in a flask, a beam of light passed through this vessel

Tyndall showed that the air was full of dust

would only be visible on each side of it but would be invisible in its interior [-] in other words we see light only because there are particles in the air which render it visible. Were there no particles all would be darkness.

Heated air is free from dust

Such being the case Tyndall found that, when the air, which was admitted to a flask, had been previously heated, as in Schwann's experiment, the beam of light was not visible in the interior showing that all or almost all the particles had been destroyed by heat – or in other words were of an organic nature. By the same method Mr. Lister has found that in Pasteur's flasks with the long open necks no dust is present after that, which was at first present, has settled.

Mr. Lister's experiments

Another method of excluding dust was published in 1873 by Mr. Lister (*Microscopical Journal* for Oct^r 1873 – see also *Trans. of Path. Soc. of London* Vol 27 – 1878). Seeing that the occasional failures which occurred in boiling fluids probably occurred from the fact that the steam might not destroy all the dust in the necks of the flasks, Mr. Lister, in addition to the precautions as to boiling under cotton wool caps &c., subjected his flasks to a high temperature previous to the introduction of the fluid. This is done by keeping them, after the cotton cap has

Method.

Preliminary heating of flasks

been applied, for two hours in an iron box. This box is of a square form with one of its sides moveable so as to form a door. "This door has its circumferential part in the form of a groove capable of being packed with a considerable mass of cotton wool. This door can be screwed by means of nuts against the edge of the box.; & the cotton wool, having the narrow rim of metal thus firmly pressed against it, serves as an effectual filter of the air that passes in during cooling. But then it is essential that the heat be so equably distributed as to avoid heating any portion of the cotton to such a degree as to destroy its physical properties. This uniformity of heat is provided for by having three shelves of sheet iron interposed between the large Bunsen's burner & the bottom of the box, so as to prevent the heat from acting directly upon it; while at the same time the box is covered over with a cover of sheet iron which reaches nearly to the ground & while it checks radiation compels the heated air to travel over the whole exterior of the box & escape by holes at the top of the cover whence it is conducted into a chimney by a tube. By these two means combined, the shelves below & the cover round about we get a uniform

browning of the cotton. Into such a box the requisite number of vessels are introduced. An aperture in the top of the box, well packed with cotton wool transmits a thermometer to show when the temperature of 300° has been reached; & when this or any higher degree short of 350° has been continued for two hours, the gas is turned off & cooling is allowed to take place; & when the apparatus is quite cool, the covered glasses may be removed with confidence that they are perfectly pure from living organisms.”

Lister's flasks with 2 orifices.

In this manner Mr. Lister purifies his flasks. The larger flasks have two necks [-] a large straight one & a lateral one – a bent spout large at the commencement & comparatively narrow at its shorter terminal part beyond the bend. The large size of the first part prevents it from ever acting as a siphon & the result is that when the liquid is poured from such a flask, & the vessel is afterwards restored to the erect position, the end of the nozzle remains filled with a drop of the liquid & this guards the orifice so that regurgitation of air can never take place through the nozzle. This drop of fluid being sucked away a pure cotton cap is tied over the orifice & the flask is kept for future use.

This flask purified by heat & with each orifice

Filling the flasks

covered with pure cotton caps, is used for the experiments. The fluid to be tested is introduced into it by a syphon consisting of two glass tubes connected by a tube of indiarubber with a stopcock in the course of the guttapercha tubing. The syphon is first completely filled with water, the temperature of which should be higher than that of the air so that there may be no dissolved air given off to form bubbles. Place one leg of the syphon into the vessel containing the fluid to be used, then turn the tap & permit a sufficient amount of fluid to flow out to ensure that all the water has escaped from the syphon; then turn off the stopcock, wash the outside of the tube with carbolic lotion, rap a mass of carbolised rag round its lower extremity, & apply this to the mouth of the flask as soon as the cotton cap is removed; then push the tube steadily down to the bottom of the flask through the carbolised rag, turn the stopcock & let the required amount of fluid flow into the flask. When this has taken place the tap is again turned off & the syphon is withdrawn through the antiseptic rag & a fresh cap of carbolised cotton (the cotton is carbolised by being soaked in a solution of 1 part of crystallized carbolic acid in 100 parts of anhydrous

ether) is tied over the mouth of the flask when the rag is withdrawn.

Purification of the fluids

These fluids are now heated for the desired length of time & then abandoned under the protection of the caps. In this way Mr. Lister has found that he can preserve turnip-infusion, hay infusion, urine, fresh milk &c. for any length of time without their undergoing any alteration. (The flask containing fresh milk is immersed in boiling water for 20 minutes).

Transference of this fluid to smaller vessels Arrangement of these.

But this is not all[,] for these fluids can be transferred to smaller vessels without undergoing any fermentation after this transference. This is done as follows; a liqueur glass is covered by a glass cap (watch glass), & the whole by a glass shade, the liqueur glass & the shade standing on a glass plate. This arrangement is introduced into the hot box & thoroughly purified. Thus we have a pure glass filled with pure air & the problem is to transfer the fluid from the flask to the glass without contamination in the process. To do this the cotton cap is removed from the nozzle of the flask & the end of this is instantly slipped into an opening in the centre of half an indiarubber ball, previously steeped in a strong watery solution of carbolic

acid. The outer glass shade is then removed &[,] the watch glass being lifted[,] the indiarubber cap is instantly applied in its place. The required quantity of fluid is then poured into the glass & the cap & shade immediately reapplied. A fresh cotton cap is now applied to the nozzle of the flask. In this manner any number of glasses may be charged & these are found to remain as pure & unaltered as the fluid in the original flask.

Lessons to be derived from Lister's experiments

And now observe what such experiments teach. In the first place into the original flask[,] when cooling[,] air enters, but this air having passed through a cotton wool plug is incapable of causing putrefaction. Then in the decanting of this liquid from the flask fresh air must enter through the large mouth of the flask but as this passes through a filter of cotton wool it is in like manner incapable of causing fermentation. Further the liqueur glasses are full of air which has either been previously heated or which has been filtered through the cotton wool around the door of the hot box. The fluid when poured from the flask into the glass mixes freely with this air but no change is set agoing. And lastly the loosely fitting glass cap & shade allow a free interchange of air but are so placed as to

make that air deposit its dust outside the glass thus answering to Pasteur's flasks with the bent necks. In spite of all these opportunities of admixture with the gases of the air all sorts of fluids remain unaltered while on the other hand the same liquids exposed freely to unfiltered air rapidly undergo fermentative changes.

These experiments are of themselves an absolute proof that the gases of the air alone are unable to cause fermentative changes in organic substances.

Roberts' method of preserving milk

In 1874 Dr. Roberts (Phil. Transactions 1874) demonstrated again that fresh milk & other substances could be prevented from putrefying when kept in a flask with a cotton plug, after having been previously boiled. His method was as follows: "An ordinary delivery pipette having on it an oblong bulb capable of containing 30-50 cub.c. was sealed hermetically at one end. The materials of the experiment were then introduced into the bulb until it was two thirds full. The inside of the neck of the bulb was next wiped dry & a plug of cotton wool was inserted about its middle. Lastly the neck was drawn out above the plug & sealed in the flame.

When the bulb was thus charged & sealed, it was

weighted with a leaden collar & submerged in the semi-upright position (so as to prevent the wetting of the cotton wool plug) in a can full of water. The can was next placed over a source of heat & boiled for the required time. The bulb was then withdrawn; &, when quite cold, its neck was filed off above the cotton wool plug. Finally it was set aside in the upright position & maintained at a suitable temperature.”

By exposure to the heat of boiling water for from 20-40 min. Roberts was able to preserve those substances with which Schroder [sic] & other observers had failed viz. milk, pieces of meat & egg albumin.

In 1876 experiments were published by Prof. Tyndall (Phil. Transactions 1876) which afford still further evidence on this subject. I have already mentioned the method by which he demonstrates the presence or absence of particles in suspension by passing a powerful beam of light through the air to be examined. He found that “in order to render air optically pure it was only necessary to leave it to itself for a sufficient time in a closed chamber or in a suitably closed vessel. The floating matter gradually attaches itself to the top & sides or sinks to the bottom, leaving behind it air possessing no scattering

He also was able to preserve other substances notably meat & egg albumin

Tyndall's experiments

His chamber

power. Sent through such air the most concentrated beam fails to render its track visible.” His method as described by himself is as follows: “A chamber or case was constructed with a glass front, its top, bottom, back & sides being of wood. At the back is a little door which opens & closes on hinges while into the sides are inserted two panes of glass, facing each other. The walls of this case are smeared with glycerine in order to make the dust adhere. The top is perforated in the middle by a hole 2 inches in diameter, closed airtight by a sheet of indiarubber. This sheet is pierced in the middle by a pin, & through the pinhole is passed the shank of a long pipette ending above in a small funnel. A circular tin collar, 2 inches in diameter, 2 inches in diameter [sic] & 1½ inches deep, surrounds the pipette, the space between both being packed with cotton wool moistened with glycerine. Thus the pipette, in moving up & down, is not only firmly clasped by the indiarubber, but it also passes through a stuffing box of sticky cotton wool. The width of the aperture closed by the indiarubber 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, airtight, the open ends of two narrow tubes intended to connect the interior space with

the atmosphere. The tubes are bent several times up & down, so as to intercept & retain the particles carried by such feeble currents as changes of temperature might cause to set in between the outer & the inner air.

The bottom of the box is pierced with holes, in which are fixed airtight, 12 test tubes, intended to contain the liquid to be exposed to the action of the moteless air.”

Method of filling & boiling the test tubes

The case so prepared is closed & allowed to stand for 3 or 4 days till it is found by the beam of light that all the dust is deposited. 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 5 minutes in a brine bath. During the cooling[,] plugs of cotton wool are introduced into the small tubes but these are afterwards withdrawn. The apparatus is then kept at a suitable temperature & 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.

Results of Tyndall's method.

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, infusions of hare, rabbit, pheasant & grouse, codfish

turbot, herring, mullet, fowl & 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.

Lessons derived from study of the method.

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

Gases from putrid substances do not cause putrefaction

But Tyndall has further shown that the gases arising from putrefying fluids[,] however foul smelling[,] cannot produce decomposition in other similar liquids although this readily occurs when

ordinary dust is admitted. Thus, “on the 30th of Nov. a quantity of animal refuse, embracing beef, fish, rabbit, hare, was placed in two large test tubes opening into a protecting chamber containing 6 tubes. On Dec^r. 13th when the refuse was in a state of noisome putrefaction, infusions of whiting, turnip, beef & mutton were placed in the other 4 tubes. They were then boiled & abandoned to the action of the foul sewer gases emitted by their two putrid companions. On Dec^r. 25th these tubes were still unchanged. On the same day the end of the pipette was dipped into one of the putrid tubes & then inserted into the turnip & on the 27th a similar speck was transferred to the whiting. These rapidly underwent decomposition while the remaining two tubes remained unaltered.”

I have confirmed Mr. Lister's results.

By operating in the manner described by Mr. Lister I have equally succeeded in preserving fresh milk, meat, cucumber or turnip infusions 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 thus preserved[,] though retaining an intense tendency to putrefaction[,] I need not say more at present.

Air acted on by Carbohic Acid cannot cause fermentation

Flasks may be freely opened under the spray

Experiment.

Not only is air which has been filtered incapable of causing fermentation in a boiled liquid, but also air which has been acted on by carbohic acid & other antiseptics. I may mention a few facts made out by myself in support of this.

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 & subsequent putrefaction but if I did the same in a spray of about 1-30 carbohic acid I could transfer fluid with ease from one flask to another without any risk[,] even though done in the most leisurely manner. To give an example; Jan^r. 30th Milk was prepared by boiling for 20 minutes in a flask purified by boiling off distilled water in it under a cotton cap.

On the same afternoon 3 tubes with glass caps & shades (just like Mr. Lister's liqueur glasses) were half filled with this milk under the spray.

Feb^r. 6th. The caps were removed under the spray &[,] a heated needle being introduced[,] portions of the fluid were taken from each tube for microscopical examination All 3 were found to present the normal appearance of fresh milk externally & microscopically.

Feb^r. 11th Examined as before. No change externally or microscopically.

[Feb] 19th No change

March 3^d. Still fluid & 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 & which had putrefied. In 3 days these milks had separated into two layers & had lost their normal characters.

Ap^r. 11th The third test tube still unchanged.

I might multiply instances of milk & other infusions 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 the latter rapidly putrefies when exposed to the air. Indeed the minute quantity which comes in contact with it can have no effect whatever - as is shown by the following experiment.

On Febr. 1st 5 pure test tubes were taken & into each was introduced 100 minims of boiled milk along with a certain number of min. of carbolic acid 1-20.

To No.I were added 2 min. making a proportion of 1-1000

“	II	“	5	“	1-400
“	III	“	10	“	1-200
“	IV	“	20	“	1-120
“	V	“	50	“	1-60

Result not due to entrance of carbolic acid into the milk

Proof of this

They were then shaken up & left exposed to the air for 24 hours, then covered with very loosely fitting caps which were removed at times during the following day.

On Febr 6th. The milks were beginning to alter in appearance & to separate into layers. This was the case even in No. V.

On Ap. 19th. They were all much advanced in decomposition.

Thus we see that decanting can be safely done in a spray of carbolic acid though the fluid still remains as putrescible as ever while in the second place experience had shown me that in this particular apartment it was very difficult to decant with success without a spray.

An experiment which I performed some time ago may be mentioned. Two flasks containing pure milk were opened in my room & left open for 10 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 & left open for 10 minutes. (Both of these remained pure, though when tested at a later period organisms rapidly developed in them.) When they were removed the spray was stopped & two fresh flasks were placed in the same position, opened, & left open for 10 minutes (one of the latter remained pure, in the

Decanting may be done under the spray

Experiment of opening flasks under spray

other organisms developed). I may state here that as will later be seen the presence of organisms is synonymous with the presence of fermentative change & their absence with the absence of such effects.

Experiment of decanting under spray

Another experiment proves the efficiency of the spray in destroying the putrefactive agents in the air very decisively. 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 in an incubator kept at the temperature of 98°F. for 4 days. 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 & the caps reapplied. These were then placed in the incubator & they remained permanently unchanged & without the developement [sic] of organisms. The same process was gone through with the other two flasks without the use of the spray. In both of these organisms developed & putrefactive changes occurred.

In this experiment when the fluid was poured from one vessel to the other it passed through the air, & air also entered into the first flask to take the place of the liquid. Where this air had not been

acted on by carboic acid organisms developed & fermentation took place, but where the air had previously passed through the spray it failed to cause any change.

Proof of value of spray from my method of purifying my vessels

A very striking proof of the value of the carboic acid spray, which occurred to me lately, may be mentioned. The flasks which I used at that time are purified by heating them to a temperature of about 600°F in a box like that described by Mr. Lister. The flasks are in the first instance heated without any covering, the cotton caps are then applied under the spray & the flask with its cap reintroduced into the box, where it is thoroughly dried in order to drive off any carboic acid which may be adhering to it. As the temperature to which the apparatus is in the first instance raised, chars cotton wool, I have used asbestos to filter the air as it passes into the interior of the box during cooling. For a time this answered quite well, but lately portions of the asbestos have become detached, & thus holes have occurred through which air can enter without being filtered, & as a result, on several occasions I have found that all the flasks so prepared were impure. This has been obviated simply by directing the spray against the door of the box as soon as the lamp which heats it is extinguished. The box is

thus surrounded by spray; the air passing into it first passes through this spray, & as a result, since I have done this I have not failed in any instance to obtain perfectly pure flasks.

Conclusions as to Boiled fluids & tissues

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

But while it cannot be doubted that this is the case with boiled fluids & tissues is it

Results as to unboiled fluids

Grape Juice
Gay Lussac's Experiment

Gay Lussac's conclusions.

equally so with unboiled? In experimenting with these substances we are met with great difficulties for it is a matter of extreme difficulty to prevent contamination of these substances. How this has been managed & with what results we must now enquire.

I. Grape juice

Gay Lussac in the research mentioned before attempted to ascertain whether Grape juice remained unfermented when oxygen gas was excluded. He took a bell jar & introduced into it small grapes intact. The jar was now reversed over mercury & was filled 5 times with hydrogen gas in order to wash out all the oxygen. The grapes were then crushed by means of an instrument introduced through the mercury, & the juice thus obtained was kept at a temperature of 15° - 20°C. Fifteen days later, no fermentation having taken place, a small quantity of oxygen was introduced & immediately fermentation occurred.

From the experiments he concludes that the oxygen introduced caused the fermentation. But here there are several fallacies. In the first place the skins of the grape were left mixed with the grape juice[,] no sufficient means having been taken to destroy any solid par-

icles adhering to them. Then the oxygen introduced might have carried in the necessary particles. There can be no doubt from Pasteur's subsequent experiments that the Torula – the cause of the alcoholic fermentation – was present on the skins of the grapes & Pasteur has further shown that oxygen is absolutely necessary for the developement [sic] of the old cells of the Torula though the young cells may go on developing without the presence of free oxygen. The explanation of Gay Lussac's experiment is that the old Torula cells present could not develop [sic] without oxygen, but that when a small quantity of oxygen was introduced, they developed & fermentation proceeded.

Van der Broeck preserved unboiled grape juice in presence of oxygen.

The next attempt to preserve grape juice of which I can find any record was made by Van der Broeck & narrated to the "Provincial Gesellschaft für Kunst und Wissenschaft zu Utrecht Jan^r. 1858." (See *Annalen der Chemie und Pharmacie* vol. 115. 1860). His method was the following.

Method.

Small beakers were filled with mercury & then heated in a sand bath till the boiling point of the mercury was almost reached. From time to time they were placed under an air pump & shaken during the pumping

for the purpose of detaching any bubbles of gas adhering to the side of the flask. This process of heating & exhausting was continued till all the air was removed from the bottom or sides of the glass. These glasses were then inverted in a basin containing previously heated mercury & were firmly fixed in this position. Ripe & uninjured grapes were now dipped into this mercury & brought under the orifice of the flask. A portion of the skin of the grape was clipped out by a heated knife & by gentle pressure some of the juice was made to ascend in the vessel, the rest of the grape being removed. When a sufficient quantity of juice had been thus introduced the vessels were placed in a room of which the temperature was 25°-28°C. & grape juice thus obtained could be kept for months or years without undergoing any change.

Rationale of the method.

In this experiment not only was all air excluded but the dust adhering to the walls of the vessel & in the mercury was subjected to strong heat & its fermentative power thus destroyed. The juice of the grape in ascending through the mercury did not come in contact with unheated dust nor did it touch the skin of the grape.

Into some of the flasks prepared[,] pure & fresh

Introduction of oxygen

oxygen was introduced from a retort containing Chlorate of Potash & oxide of copper. (The nozzle of the flask was heated previously to its immersion in the mercury & the oxygen was allowed to stream out for a time sufficient to wash out all the dust. In none of these flasks was there a trace of fermentation.

Filtered air was equally harmless

Again atmospheric air was forced through a mass of cotton wool & then introduced in the same manner but without producing any effect.

Introduction of yeast followed by fermentation

Then yeast was introduced in minute quantity & fermentation at once commenced. And young cells which had never been exposed to oxygen were introduced by a method which is fully described in his research & also caused fermentation[,] thus proving that oxygen is not necessary even for the commencement of the change if only the yeast cells be young (3 or 4 days old.)

Results

By these experiments it was absolutely demonstrated 1. That oxygen is not the cause of the fermentation of grape juice & 2. That the juice itself contains no ferment.

Pasteur's experiments.

That the juice contains no ferment was further demonstrated by Pasteur (Études sur la Bière) who introduced into flasks with bent necks containing pure boiled juice some unboiled

juice. No fermentation occurred[,] though if a single torula cell had been added the whole mass would have fermented.

Roberts' Experiments

Dr. Roberts (Phil. transactions 1874) likewise succeeded with grape juice. Test tubes were drawn out at the lower ends into capillary points & sealed in the flame. The upper ends were plugged with cotton wool. They were then passed & repassed through the flame of a spirit lamp until they were quite hot as shown by the commencing charring of the cotton.

Method.

“Eleven sterilized tubes, 6 empty & 5 containing water, were charged with grape juice in the following manner: a fresh grape was firmly seized with the fingers & thumb & a spot on its surface was pressed for a few seconds against the flame of a spirit lamp so as to destroy any adhering germs. The point of the sterilized tube – also heated in the flame & quickly snipped off by an assistant was then thrust into the grape at the heated spot. Compression was now made on the grape until a sufficient quantity of the turbid juice was forced into the tube. The tube was then withdrawn & its point sealed in the flame. The 11 tubes thus charged remained permanently unchanged & when examined at various periods from 5-8 weeks the taste & reaction of their contents were indistinguishable from that of the fresh grape juice.

Result.

Blood.

Van der Broeck
Method.

Results

Pasteur

II. Blood.

Blood is one of the substances which has been frequently referred to as having an inherent tendency to decompose but several experiments have now demonstrated that this is not the case.

The first observer who succeeded in preserving blood was Van der Broeck. He proceeded as follows. Having prepared his flasks filled with mercury as formerly described he introduced one end of a previously heated copper tube into the carotid artery of a dog. To the other end of this a caoutchouc tube was connected, while the free end of the latter was dipped into the mercury & the blood passed along into the vessels purified as previously described. (This caoutchouc tube had been purified by the passage of steam through it for some time & then during cooling a plug of cotton wool was placed in each end.) The vessels were then kept at a temp. of 25° - 30°C. for weeks without the contained blood undergoing any change. Into some of these flasks oxygen was introduced as also filtered air but still there was no putrefaction. The minutest portion of putrescent or even non putrescent but unheated substance at once set up fermentation.

In 1863 Pasteur (Comptes Rendus t. LVI p.738.) stated that he had obtained blood from healthy animals by means preventing contamination with unheated atmospheric dust & that this blood remained free from change. In a

Pasteur's method of purifying the flask &c.

later publication (*Etudes sur la Bière* 1870) he describes the method pursued.

“For this purpose I made use of a flask connected by means of a caoutchouc tube with a brass stop cock. The two branches of the cock are about 12 centimetres in diameter, that which is free is somewhat filed down like the extremity of a canula. In order to cleanse this vessel from all living dust the free extremity of the brass tube was connected with a platinum tube strongly heated, a small quantity of water being previously introduced into the flask. This having been boiled off the flask is allowed to cool, the air which enters being previously heated. It is well to boil the water in the flask under pressure – the free extremity of the platinum tube being connected with a glass tube bent at right angles & dipping into a deep vessel filled with mercury. After boiling for some time under pressure, this tube is detached & boiling is continued at the ordinary pressure, then the flask is allowed to cool & to become filled with heated air. When the flask is cold the cock is shut & the platinum tube detached. Before use the mouth of the brass tube is kept down in order to prevent dust falling into it. Before being used this portion is heated carefully in the flame of a spirit lamp.

Method of obtaining the blood.

A living dog is now taken, a vein or artery is opened & the end of the brass tube introduced. When

Result.

this has been secured by a ligature, the cock is opened. Blood then flows into the flask & when enough has been obtained the cock is shut & the flask placed at a suitable temperature. As a result this blood does not putrefy & its odour generally remains quite fresh. There is not even an active absorption of oxygen for after several weeks only 2 or 3 p.c. of that gas was found to have disappeared in the case of a closed vessel.

Burdon Sanderson's results

Dr. Burdon Sanderson (Quarterly Journal for Microscopical Science Vol XI 1871.) also found that blood taken from rabbits with suitable precautions & put into purified glasses, covered by cotton wool, remained free from change.

Roberts. Method & results.

Dr. Roberts (loc. cit.) having purified his tubes in the way described & having thoroughly cleansed his finger[,] punctured it & sucked up about 2 drops into several tubes. Of 10 tubes prepared in this way 6 remained unaltered. This experiment is of little value partly on account of the imperfect method of experimentation & partly on account of the small amount of blood obtained.

Lister. Method.

Mr. Lister (Microscopical Journal 1878) obtained blood from the jugular vein of an ox as follows. A large glass tube was fixed in the large orifice of one of his double necked flasks[,] the interval between the flask & the tube being filled with tightly packed cotton wool. Over the end of this glass tube which is of course open in the interior of the

flask a cotton cap is applied & there is a cotton cap as usual over the orifice of the spout. The flask thus arranged is heated in the hot box. The jugular vein of an ox[,] being now exposed antiseptically[,] is divided, the cotton cap removed from the end of the tube & the end of the vein slipped over the orifice of the tube. Blood thus flows through a pure tube into a pure flask. Then when enough is obtained the vein is removed & a cotton cap immediately applied in its stead. Before coagulation has occurred various liqueur glasses arranged as formerly described are charged from the large flask. The blood in the flask & in the liqueur glasses remained unaltered though kept for 6 weeks.

And Mr. Lister found that not only blood but blood & water (a much more putrescible mixture) remained unaltered. The water was introduced into the large pure flask & [struck through: *arranged with its tube as before described & was then*] boiled so as to purify it. A portion of blood clot from one of the liqueur glasses was then spooned into the flask[,] careful precautions being taken against the entrance of living dust.

In some experiments performed in a manner to be shortly described I found that blood may be removed from the healthy living body & placed in calcined

Fills other vessels

Result

Blood & water may also be preserved.

My own results

flasks or in flasks containing infusion of cucumber & be preserved an indefinite length of time without alteration.

Hence blood has no inherent tendency to undergo fermentative changes nor can oxygen induce such alterations.

Urine

Van der Broeck

Method

III. Urine

Healthy urine was first preserved without alteration by Van der Broeck. The flasks in which it was received were prepared as before described. An animal (dog or sheep) being killed, the abdomen was immediately cut open & the ureters & urethra rapidly tied. The bladder thus isolated was removed & immersed in the mercury. A heated needle was then introduced & the bladder was torn, the urine thus ascending into the glass. This urine remained pure even after the addition of oxygen or filtered air.

Pasteur

Method.

In the same paper in which Pasteur mentions that he has succeeded in preserving blood he states that he has also obtained pure urine. The method is described in his "Études sur la Bière." The flask with its nozzle & stop cock are prepared as in the case of the blood, then the free extremity of the brass tube is introduced into the urethra. Urine being passed, the stop cock is turned & the urine flows into the flask. Urine thus obtained undergoes no fermentation. "Elle dépose des cristaux en petite

Result

quantité mais sans se troubler ni se putréfier d'aucune façon.”

Lister - method

In 1871 Mr. Lister succeeded in obtaining & preserving pure urine as follows: (Transactions of the Royal Society of Edinburgh 1875.) The method he employs is to wash the meatus urinarius & the glans penis with 1-40 carbolic lotion. A prepared flask is then taken, the cotton cap is removed & the glans immediately applied over the orifice & urine passed into the flask. Fresh cotton caps are then applied. This urine may like other fluids be decanted into liqueur glasses. This experiment is constantly successful[,] no alteration occurring in the flasks or in the glasses.

Result

My own experiments & results

I may here state that I have often repeated this experiment with the view of obtaining pure unboiled urine for other experiments & always with success. I have however used the spray & thus avoided the necessity of applying the glans penis to the orifice of the flask. The glans having been purified urine is simply passed in a spray of carbolic acid into a pure flask

Roberts' method

Dr. Roberts also obtained similar results by passing urine into a pure test tube & afterwards charging tubes of the form previously described by breaking off the capillary end below & letting the urine flow up. Of 8 tubes so obtained 7 remained unaltered while one putrefied.

Cazeneuve & Livon (Revue Mensuelle 1877 p.733)

Cazeneuve & Livon preserved urine in the bladder

Method

Conclusions.

Milk

Hoppe Seyler failed to preserve it but showed that oxygen was not the cause of the fermentation

succeeded in preserving urine unaltered in the bladder.

A ligature is placed around the prepuce of a dog for 5 hours in order to have a considerable amount of urine in its bladder. An incision being made into the bladder, at the end of that time, the ureters & the urethra were ligatured & the bladder was cut out. The bladder was then suspended in the air at a temp. of about 25°C. It soon dries & though liquid slowly transudes[,] it evaporates immediately & thus the bladder wall cannot putrefy. Urine may thus be kept for several days without undergoing any change although if the bladder be opened it becomes ammoniacal in 24 hours. I shall return to these experiments at a later period.

Thus healthy unboiled urine has no inherent tendency to putrefy but follows the same law in this respect as boiled fluids.

IV. Milk.

In 1859 Hoppe Seyler attempted to preserve milk pure in the following manner (Virchows Archiv Bd. 17. 1859). A small funnel was carefully fastened over the teat of a goat. To the lower end of this was attached a piece of caoutchouc tubing which also was attached to a glass tube below. This glass tube passed down to the bottom of a glass test tube, the upper rim of which was provided with a piece of caoutchouc tubing open above. None of the tubes were heated nor in any way purified. The milk was now withdrawn in a

continuous stream so as to flow for a long time over the edge of the caoutchouc tube till it was quite free from bubbles of air. The test tube was then lowered but before the upper tube was completely out of the liquid & while the milk was still flowing the caoutchouc tube was firmly tied over a thick glass rod.

Milk preserved thus at the ordinary temperature coagulated in 3 days. Hoppe Seyler therefore concludes that milk contains a ferment when shed.

This experiment proves that oxygen is not necessary for the occurrence of fermentation in milk, in other words it is not the cause of such changes and therefore, as the tubes were not purified the cause must either be in the milk itself or be something adhering to the tubes.

Which of these is the true agent is decided by the following experiments performed by Dr. Roberts (loc. cit.).

“A glass tube was drawn out at each end to a narrow orifice. The lesser portion of this was tightly wrapped round with cotton wool & inserted as a plug into a large test tube containing water to the depth of one inch. A cap of cotton wool was also tied over the upper narrow orifice. The water in the test tube was then briskly boiled & the boiling was continued almost to dryness. When the apparatus was cold, I took it into the cow house &, seizing a teat I pulled off quickly the cotton wool cap & pushed the narrow

Roberts.
Method.

point into the duct of the teat. Holding it firmly in this position I milked into the test tube until sufficient milk had been obtained. I then drew away the test tube from the little tube, pressing in the cotton wool around it as I did so, until the latter was entirely withdrawn from the test tube.

Result

From the test tube I charged 10 empty pure tubes” in the manner described under urine “& resealed their capillary orifices. Of these 10 tubes 3 remained unchanged, the milk remaining perfectly normal as regards taste, reaction &c. The other tubes curdled or putrefied in 10 days.”

The method described here is imperfect but the fact that 3 tubes remained unaltered absolutely demonstrates that the cause of the fermentation is nothing inherent in the milk itself but something which it acquired after coming out of the body – that something being particulate, not gaseous.

Lister's experiments

Mr. Lister (Microscop. Journ. 1878) describes several series of experiments performed with the same aim. In one of these he succeeded in preserving the milk unaltered.

Method

24 little tubes were prepared by heating & covered with glass caps & shades. After a rainy day he washed the udder of the cow & the hands of the milkman with water. Then a funnel connected with an electric tube was placed

over the nipple (the glass tube had been heated & the elastic boiled). This funnel was filled with milk & through it each tube in succession had a small quantity introduced by relaxing the elastic tube. Of these 24 two remained permanently pure. The results in the other tubes equally demonstrate that the cause of fermentation is not inherent in the milk for they each underwent a different change. These will be more fully considered later.

V. Egg albumen [added in pencil: *My own*]

The difficulty experienced by Schroeder in preserving the white & yellow of eggs will be remembered. Van der Broeck introduced an egg into the mercury[,] broke the shell with an iron rod, stirred up the contents of the egg with a similar rod & then allowed them to ascend into the glass. This remained pure even with subsequent addition of oxygen gas or of filtered air.

Gayon (*Comptes Rendus* vol. 76 & 77) found that some eggs may be preserved unaltered while others undergo change. He supposes that in the latter case the causes of putrefaction were admitted in the oviduct.

Roberts proceeded in the following manner. 8 sterilized tubes were prepared containing pure water.

“A fresh egg was fixed in a convenient support & a small piece of the shell was chipped off, care being taken to leave the subjacent membrane uninjured. Then a sterilized bulb was taken & the capillary portion immersed for a

Egg albumin [sic] [Added in pencil: *Shetland*]

Van der Broeck's method & results

Gayon

Roberts obtained & kept it pure

few seconds in boiling water in order to destroy any adherent septic particles. The sealed end was then rapidly snipped off & the capillary portion plunged into the interior of the egg. About 2 cub. cm. of the albumen was then sucked up by the mouth into the bulb. When this was accomplished, the bulb was quickly withdrawn & its capillary end sealed in the flame." 6 of these 8 tubes remained unaltered for 7 months.

Of a second series of 7 tubes similarly charged & kept for 2 months, 5 remained unaltered. That is, of 15 tubes used 11 remained pure.

[Added in pencil: *My own*] Hence egg albumen has no inherent tendency to undergo fermentative changes.

VI. Vegetable tissues.

Dr. Roberts has also experimented on the solid tissues of the turnip, potatoe [sic], orange, & tomato with similar success.

The following is his method for turnip.

"A sterilized tube containing water was nicked with a file near the base of the capillary part, where the tube had a diameter of about 2 millimetres. A fresh oblong turnip was then fractured across & 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 & its end sealed with melted

Results [Note in pencil: *Egg in beakers[?]*]

Vegetable tissues

Roberts.

Results.

Method.

sealing wax. Of 14 tubes charged with turnip 10 were successful

7	potato	4
8	orange	8
3	tomato	3

Conclusions

Therefore there are not present in vegetable cells ferments which induce changes after death.

Animal tissues

Billroth & Tiegel did not succeed

VII. Animal tissues.

Some years ago experiments were made by Billroth (cocci bacteria septica) & Tiegel (Virchow's [sic] Archiv vol. 60) 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 & removed with heated implements various portions of tissue such as liver, spleen, kidney &c & 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 & act on the interior of the tissue. At the same time for the future the organs would be protected from air or dust.

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

These experiments were repeated by Dr. Burdon Sanderson

Burdon Sanderson likewise failed.

Objections to the method.

Heated paraffin is dry heat

Paraffin solidifies at a low temperature

During cooling dust falls into it & is not destroyed

Paraffin is apt to crack

Objection to method of removing the tissue

who obtained similar results & adopted the same views.

But if 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 [sic] its power of fermentation.

Further paraffin solidifies at about 52°C or even lower & therefore melted paraffin 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 & sink on to the tissue. Then again on the sides & bottom of the vessel is coarser dust which likewise may not be destroyed.

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

Then again the knife before dividing the tissue compresses the vessels & forces the blood out of them & thus when these vessels are cut air is sucked in & 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

My own experiments

on this subject & these have been continued at intervals since that time.

First experiment

The first experiment was an imitation of those of Billroth & Tiegel & yielded conflicting results. Thus the liver & kidneys putrefied while the spleen, muscle & mesentery remained unaltered.

My method

This being the case I determined to abandon this method entirely & to see if some definite conclusions might not be arrived at in some other way.

A number of beakers each provided with a cotton cap were purified by heat somewhat after Mr. Lister's method & into each vessel about $\frac{1}{4}$ of its volume of pure turnip infusion was introduced from one of Mr. Lister's double necked flasks. This was done under the spray & the cotton caps were then reapplied. These beakers were then placed in an incubator kept at the temp. of 98°F. for 3 or 4 days. At the end of that time the turnip infusion was clear & unaltered & they were therefore considered to be ready for use.

Experiment

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

Method of obtaining the tissues

The skin & 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 & the abdominal

cavity was opened under a distant spray of carbolic acid with purified & heated instruments. Portions of its organs & tissues were rapidly cut out & introduced into the beakers in the spray.

Into the 4 vessels containing the pure turnip infusion portions of liver, spleen, kidney & muscle respectively were introduced &[,] the caps having been reapplied while the flasks were still in the spray[,] they were then placed in an incubator.

Into the 6 flasks containing melted paraffin portions of liver, kidney, spleen, muscle, mesentery & vena cava with its blood were dropped [added in pencil: *also under the spray*]. These were then left to solidify & placed in the incubator.

Results of experiment

All those portions of organs introduced into the turnip infusion remained permanently pure & free from putrefaction.

Of the paraffin beakers 2 (muscle & vena cava) remained without change while the other 4 – (liver, spleen, kidney & mesentery) putrefied.

Considerations derived from the method

In this experiment we have in the first case a series of beakers heated so as to destroy the activity of the dust[,] & that this was effectually done was proved by the fact that the turnip infusion remained in them without undergoing any change, although had ordinary dust been present, as has been amply shown in the foregoing experiments, this in-

fusion would have undergone putrefaction. Then the portions of 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 is perfectly potent to destroy the fermenting power of dust. Such being the case, if the tissue, taken with all precautions undergoes putrefaction, it will in all probability have contained the causes of this fermentation 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 the unboiled tissues, remaining unaltered, had no inherent tendency to undergo fermentations even when freely exposed to the air.

Further improvements in the method

I used the turnip infusion partly because I wished to know if the beakers had been thoroughly purified & partly in order to keep the tissue moist, for I had found in a former experiment that they dried, in the open-mouthed vessel, too rapidly. Since that time I have used cucumber infusion as being still more putrescible.

Advantages of the method

Further by the use of these infusions the conditions favouring putrefaction are greater

for we have here a boiled, highly putrescible infusion of cucumber & an unboiled, if possible more putrescible unboiled [sic] infusion of meat, & the meat itself. It were hardly possible to provide more favourable conditions for putrefaction. 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 experiment any of the supposed causes of failure might have been in operation but in the second experiment the entrance of septic laden air 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 occurring later.

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 with one of the portions of tissue & in this flask putrefaction occurred rapidly. Again the fact that 4 paraffin flasks went wrong (the organs being there also subjected to the

Possible errors in the method of Billroth & Tiegel

Test experiments
Failures

spray) shows that this had no influence. Again when the gall bladder is wounded fermentation often occurs thus:-

Failure from wounding the gall bladder

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 & was now rapidly opened under the spray. Into 7 beakers containing pure cucumber infusion, 2 pieces of liver, one piece of each kidney, one piece of spleen, one of muscle, & one of mesentery were introduced. In taking the liver the gall bladder was injured.

Four weeks later 5 beakers were unaltered, the two which had putrefied being the two pieces of liver which indeed were putrid 24 hours after removal from the body.

Additional test by previous injection of putrid matters into the animal

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 & preserved undergo putrefaction.

Several conclusions

I have repeated these experiments many times with the same results & I therefore conclude that the tissues of the healthy living body like the fluids, contain no ferment capable of putrefaction after death & remain pure in flasks so long as the dust of the atmosphere is excluded. (In some instance the heart with its contained blood was also removed & remained like

the other tissues, unaltered. Rabbits were the animals used for the experiments).

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

On reviewing the mass of evidence before us we have it distinctly shown that boiled fluids & tissues have no inherent tendency to undergo fermentative changes, that oxygen, whether pure, nascent, or mixed with nitrogen in the proportions present in air can not 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 the flask containing the fluid very slowly or be allowed to remain at rest for a long time before reaching the fluid (as in Pasteur's cellar experiment to be afterwards mentioned), or be acted on by a spray of carbolic acid.

Thus the material in the air causing putrefaction is not a gas, for that would be continuous & would not be removable by filtration or by rest, but it is something discontinuous, something heavier than

Review of the evidence as to fermentation in boiled & unboiled substances

Conclusions

air – something particulate. These particles may be deprived of their power of causing fermentation by the action of chemical substances as sulphuric & carbolic acids & 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 have no such inherent tendency.

Behaviour of unboiled fluids in the living body

And not only do unboiled fluids & tissues in flasks 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. The same is the case in the hemorrhages into joints in haemophilia, hemorrhages into the brain &c. We know what happens if we cut into any of these extravasations & admit dust-laden air

into them. The blood which we found odourless, & it may be clotted, becomes in a few hours foul smelling, liquefies & soon disappears; it has in fact putrefied just as it does when kept in a flask without exclusion of dust.

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

Behaviour of dead tissues

And not only is this the case with fluids, it is also the case with tissues. In a fracture many portions of the tissue are cut off from their vascular supply, or killed by the violence causing the injury, & yet they do not decompose, they do not slough, they disappear by absorption. Yet if the same injury be not subcutaneous & the injured parts be exposed to ordinary air they putrefy & 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 in similar cases affecting the integuments, extremities &c.[,] death occurs [-] putrefaction & sloughing follow it 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 & an open sore is left, the blood & 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 of an organic nature which are present in varying quantities in the surrounding air & 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 before they gain the wounds in some way or other as for instance as previously seen by the use of carbolic acid.

It is on this principle that aseptic surgery, as introduced by Mr. Lister, is based.

Causes of fermentation are

Method of preventing putrefaction

Aseptic Surgery – Definition

I prefer the term “aseptic” to indicate this form of antiseptic surgery because as we shall see there are many different forms of treatment which deserve the name of “Antiseptic” but this is the only form which can truly bear the name “Aseptic”. In other words there are many attempts to prevent sepsis but they all go on an imperfect principle with the exception of that introduced by Mr. Lister which[,] founded on a true principle[,] attains the ideal of results, a complete absence of sepsis – an asepsis. His method then is best designated by the term expressing its result – Aseptic.

Problem to be solved.

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Aseptic Surgery

is that form of antiseptic treatment introduced into surgical practice 15 years ago by Joseph Lister. It is founded on the principle indicated on the preceding page (-) the exclusion of active ferments. Theoretically this is the ideal form of antiseptic surgery for here, supposing the attempt to be successful, the causes of putrefaction cannot enter the wound in a state capable of producing fermentation & therefore decomposition of the discharges or of dead portions of tissue &c. cannot possibly occur.

The problem which Mr. Lister had to solve, & the method he employs to do so, may be shortly stated as follows:

On all objects in the external world septic dust is present, on the skin of the patient, on the hands of the surgeon & his assistants, on all instruments, in water &c & when a wound is made any introduction of this dust into the wound must be completely avoided. Further the air containing many of these particles must be in some way or other cleansed of them. Then after the wound has been made care must be taken to prevent their entrance during the after treatment. Some sort of dressing must be provided which shall

prevent their passage in a living state & at each change of this dressing the problem is the same as at the time of infliction of the wound.

Such being the question at issue I must now proceed to the means by which it is solved. [Next part struck through in pencil] And I may here state that what follows is in the main what I have learned from long & constant attendance on Mr. Lister's practice though a good deal of what is stated especially with regard to country practice, war &c is my own. The principle is solely Mr. Lister's, the means by which it is carried out may be various. [End of striking through]

I shall first enumerate the substances used in Aseptic Surgery.

Carbolic acid is the antiseptic employed to destroy the particles in the air & on surrounding objects which give rise to putrefaction. It is obtained in the solid form & of extreme purity from Bowdler & Bickerdike, Church, Lancashire. It is used in various forms.

The carbolic lotions used are of two strengths 1-20 & 1-40[,] one part of crystallized carbolic acid dissolved in 20 or 40 parts of water respectively. This is kept in a stopped bottle to prevent evaporation of the acid. It ought to be quite clear. Where it is not & more especially where globules of oily material are present, it is impure – the oily particles are particles of cresylic acid. It is a mistake to add alcohol or glycerine to aid the solubility of the acid because these substances hold the acid more strongly than water & it

Substances employed in Aseptic Surgery

Carbolic acid

Carbolic lotions

Pure carbolic acid

is thus not so potent for producing an instantaneous effect.

Carbolic acid may in some cases be required pure[,] being liquefied by the addition of a few drops of water. This is especially used for injecting næri &c.

Alcoholic solution

A solution of carbolic acid in methylated spirit or in rectified spirit in the proportion of 1-5 is used for the purpose of purifying wounds inflicted some 24 or 36 hours before being seen.

Carbolic oil

Carbolic oil is also used in various proportions as 1-5; 1-10; & 1-20 consisting of carbolic acid mixed with olive oil in the foregoing proportions.

1-5

Carbolic oil 1-5 is but rarely used though it is occasionally applied as a dressing to putrid wounds when one wishes to purify them. It is chiefly known as the solution in which catgut is permanently preserved.

1-10

Carbolic acid 1-10 is used as a dressing in the neighbourhood of the anus, penis &c.

1-20

Carbolic oil 1-20 is used for oiling catheters &c before their introduction into the bladder. Carbolic acid of this strength does not seem to be too much for the mucous membrane of the urethra while it secures against the introduction of matters into the bladder which are capable of causing putrefaction.

Objections to oily dressings

There are various objections to these oily dressings. For carbolic acid is very rapidly washed out by the discharge & further they are very dirty more especially

rimming indiarubber tissues.

The latter disadvantage is got rid of by the use of carbolic glycerine of two strengths 1-5 & 1-10. This is employed for dressing in the circumstances in which the oil has been generally used.

A spray of carbolic acid is generally employed in order to purify the atmosphere. These were formerly driven by hand but of late Mr. Lister has introduced a steam spray. I need not here describe the apparatus more especially as they can easily be obtained of Mr. Lister's pattern from David Marr, 27 Little Queen St, Holbourn W.C. They consist of the following parts. A boiler which contains water boiled by a spirit lamp. The steam issues through a tube placed at an angle to another more upright one through which carbolic acid 1-20 - which is placed in the retort - is sucked up. This one to 20 carbolic acid mixing with the steam makes a spray of about 1-30 or 1-35. The carbolic acid passes through a sponge at the bottom of the upright tube which filters it & thus prevents the minute orifice of this tube from becoming choked.

The catgut used for tying the vessels &c. is prepared in the following manner. The ordinary catgut of commerce if placed in water becomes too supple, it swells up & thus cannot be threaded, while its swollen condition weakens the smaller fibres. If it be placed in oil the gut

Glycerine solutions

Carbolic spray

Carbolised Catgut

remains rigid & no oil enters its substance. A very minute quantity of water renders the gut supple while it does not materially weaken it. It is therefore prepared by placing it in a solution of carbolic acid in oil 1-5 with a very small quantity of water [added in red ink: *10 per cent of water*] diffused through the oil. As the water ultimately falls to the bottom a few pebbles are placed on the bottom of the vessel, on which the catgut rests & thus it does not come in contact with the pure water. As a result of keeping it in this solution catgut first becomes supple & soft but afterwards harder & firmer & does not readily swell up in fluids. The longer it is kept the better it becomes, carried conveniently wound on a reel, kept in a German silver case.

Carbolised silk

Carbolised silk is often used as ligatures[?] & is prepared as follows, 9 parts of beeswax and one part of carbolic acid are melted together. Silk thread of various sizes is steeped for a while in this. As the thread is taken out of the melted mixture it is drawn through a cloth in order to remove the superfluous wax. This wax holds the carbolic acid, makes the thread more useful & fills up its interstices, thus preventing it from becoming soaked with fluids. The carbolised silk thus prepared is kept permanently in stopped bottles or wrapt [sic] in carbolic gauze. It must not be steeped for any length of time in the lotion before being used for that would open out the threads & spoil it. If

properly kept, the interior is aseptic or even antiseptic & the drawing of the thread through the finger moistened with carbolic lotion is sufficient to destroy any septic dust adhering to its outside.

Protective. Preparation

Rationale of the method

In order to protect healing wounds from the irritation of carbolic acid a special material is employed termed the Protective. This consists of oiled silk coated with copal varnish. When this is dry a mixture of one part of dextrin, two parts of powdered starch, and 16 parts of cold watery solution of carbolic acid (1-20) is brushed over the surface. The rationale of this method of prep. is the following. Oiled silk alone is better than gutta percha tissue because carbolic acid does not so readily pass through it. It does however do so & therefore the copal varnish is added which is almost absolutely impermeable to carbolic acid. As however the fluid collects on this, as on a duck's back, leaving intervals between each drop on which dust may fall & not be acted on by the acid, the dextrine solution is added & the result is that when moistened the whole surface of the protective remains uniformly wet. The use of the carbolic acid in the dextrine solution is not to add any carbolic acid to the protective but because it is better than water for enabling the dextrine to adhere. For the same reason the powdered starch is added. The original carbolic acid flies off very quickly from the protective.

Carbolic gauze is the substance generally employed

Carbolic gauze

[In pencil] The proven[?] formula was 1-5-7

Rationale of the preparation

Method of preserving the gauze

as a dressing to guard against the entrance of putrefaction after an operation. The gauze used is ordinary fine unbleached tarlatan, washed & dried. It is folded in pieces of 6 yards each & these are placed in layers above each other in a tin case[,] the walls of which are surrounded by water which is boiled by a lamp beneath. When thoroughly hot they are impregnated with the following solution:

Crystallised carbolic acid		1 part
Common resin	[Has crossed out 5 parts]	4 parts
Paraffin	[Has crossed out 7 parts]	4 parts

The resin & paraffin are melted together & then the carbolic acid is gradually added. This melted mixture is sprinkled over the gauze layer by layer by means of a syringe & when this has been completed a heavy weight is placed over the gauze & the heat continued for a suitable period. The amount of solution added must be about equal to the weight of the gauze.

In this gauze the carbolic acid is the only active agent – the resin is used to hold the acid – to prevent its being washed out too soon by the discharge while the paraffin is employed to lessen the adhesiveness of the resin. The gauze ought to be kept in a tin box closing lightly to prevent evaporation of the carbolic acid. It is used either in the form of loose gauze, or made up in a dressing, or torn up into bandages.

Latest formula

Von Bruns has introduced a gauze containing castor oil instead of the paraffin. This gauze is cheaper & softer.

[In pencil] For formula see Macconagh[?] p.122

Mackintosh

Method of using it

Cleansing of Sponges.

Boracic acid

Boracic lotion

[Struck through] I note lately Mr. Lister has altered his formula to the following

Crystallized carbolic acid	1 part
Common resin	4 parts
Paraffin	4 parts

[End of striking through – this is presumably struck through because he has already corrected it on the previous page.]

To prevent the discharge soaking directly through this gauze Mackintosh cloth is used. This is cloth with a thin layer of indiarubber spread on one side. It is placed outside the dressing (generally one layer of the gauze comes outside it, partly in order to keep it in position & partly also in case any hole should exist in the mackintosh, to have a little antiseptic material outside) care being taken that the side on which the indiarubber is spread goes next the wound. If the other side be placed inwards it absorbs discharge & not being antiseptic it becomes in reality a piece of impure cotton in the interior of the dressing & may thus communicate putrefaction inwards and the mackintosh itself also gets spoilt.

Sponges are washed after an operation & are then kept soaking in a jar containing carbolic acid 1-20 till required. During an operation they are washed in 1-40 carbolic acid lotion.

When the wound becomes superficial boracic acid in various forms is used.

Boracic lotion is a cold saturated solution of boracic acid ($B_2O_3, 3H_2O$) in water. This acid is soluble in 25 to 30

parts of cold water & in very much larger quantity when the water is boiling. It is convenient to tinge this solution with litmus to distinguish it from the carbolic lotions.

Boracic lint

Boracic lint is ordinary surgical lint soaked in a hot saturated solution of boracic acid & then hung up to dry. It contains about half its weight of crystals of the acid. This is also stained by litmus.

Salicylic cream

Salicylic cream is used for applying around a wound when a dressing is to be left on for some days. It prevents irritation by the discharge. It formerly consisted of salicylic acid crystals mixed with 1-20 carbolic acid lotion to the consistence of a cream. This is apt to separate into two layers & therefore it is better to make a cream by mixing salicylic acid into a paste with glycerine. This latter cream remains of uniform consistence & is easily applied.

Chloride of zinc

For the purpose of purifying sinuses, putrid ulcers &c. a solution of chloride of zinc is used of the strength of 40 grs. to the oz. of water. This is either applied on lint to the whole surface of a wound or it is injected by means of a syringe & catheter into all the deep parts, its free exit being permitted. If the exit of this solution is obstructed it may pass up among the tissues & cause gangrene. There are generally some undissolved particles of chloride of zinc at the bottom of the bottle. It is therefore well not to shake it

Iodoform

before use as these particles are so many pieces of caustic.

Iodoform is now applied to the surface of ulcers & answers the same purpose as the chloride of zinc solution while it causes no pain.

Boracic ointments

Various forms of Boracic ointment are used as applications in certain cases. Two strengths are employed – full strength & half strength, the former being best over cavities, the latter over a surface which one wishes to heal.

The following is the original formula for the full strength ointment.

Boracic acid crystals	1 part
White wax	1 part
Paraffin	2 parts
Almond oil	2 parts

First mix the wax & paraffin by heating them together, then add the oil. Then mix the crystals with this in a warm mortar & continues [sic] the process of mixing till the liquid solidifies. Spread on thin cotton cloth.

The half strength contains half the quantity of Boracic acid.

A much softer & more suitable boracic ointment is made with Vaseline.

Carbolised cotton wool

[Added in pencil: *Salicylic ointment* and *Get formula*]. Carbolised cotton wool is used in some cases of gangrene. It is obtained by soaking pure cotton wool in a solution of carbolic acid in anhydrous ether 1 p.c. & then drying.

Method of using the materials

Such are the chief materials employed in aseptic surgery as practiced by Mr. Lister. Let us now consider how they may be best used.

Typical operation

Take as an example of an operation the removal of a fatty tumour say from the back.

Purification of skin of patient

The patient having been brought under the influence of chloroform or other anæsthetic the skin over the tumour & for some distance in the vicinity is thoroughly purified from any active dust by washing it well with a solution of carbolic acid 1-20. The surgeon & his assistants also wash their hands in 1-40 carbolic lotion while the instruments are put to soak in 1-20. A towel is arranged close to the tumour –generally on the part of the table between the operator & the patient, which towel has been well soaked in 1-20 carbolic lotion & is meant as an antiseptic basis on which instruments may be laid during the course of the operation without any fear of their contamination. This towel is so arranged as to be within the cloud of spray. A spray being now made to play over the part at a convenient distance[,] the surgeon makes his incisions, removes the tumour, ties the vessels with catgut, introduces a suitable drain, stitches up the wound, applies a piece of protective but little larger than the wound[,] which protective has been of course dipped in the 1-40 carbolic

- of hands of surgeon

pure basis

Spray.

hemorrhage
drain

stitches
protective

Wet gauze

Dry gauze

Dressing

Gauze bandage

Elastic bandage.

After treatment

Consideration of each step in detail

lotion. Outside this a piece – several layers – of loose gauze [*is applied* has been crossed out] which has been soaking for some time in the 1-40 carbolic solution. This wet gauze & protective are called the deep dressing. The hot gauze must overlap the protective in all directions. Then any remaining hollow is filled up with loose gauze & outside the whole a gauze dressing is fixed. This dressing consists of a suitable sized piece of carbolic gauze folded in 8 layers, beneath the outer layer of which the mackintosh is placed with the mackintosh side inwards. The dressing is fixed by means of a gauze bandage & when this is accomplished the spray may be stopped. Then around the edges of the dressing an elastic bandage is applied so as to keep the edge constantly applied & to allow no interval to occur between the dressing & the skin during the movements of the patient. The elastic is carefully pinned by means of safety pins to the edge of the dressing. In this particular instance to prevent the dressing from slipping up or down braces would be passed over the shoulders & between the thighs.

In the after progress of the case the dressing is changed according to the amount of discharge though in no case is it left on longer than 8 days. Such is very briefly a sketch of an operation performed aseptically. I shall now consider

each step in detail & point out the most frequent sources of failure in carrying out the experiment[,] for the whole operation as far as regards the avoidance of putrefaction is as much an experiment as if it were performed on fluid contained in glass vessels.

Purification of the skin
with 1-20 carbolic lotion

The first thing then is to purify the skin in the neighbourhood of the seat of operation. This is necessary because the skin is covered with dust. The natural grease of the skin also is not easily removed by simple washing & protects the septic particles present beneath it & in the hair or sebaceous follicles. This purification of the skin is carried out by washing it well with 1-20 carbolic lotion & allowing this to act some little time. It is well, having first washed the neighbourhood thoroughly to apply a large rag or towel dipped in one to 20 & allow it to remain for some minutes. Where the epidermis is thick it is well to have this towel applied about half an hour before the operation. It is not necessary to wash with soap & water or with alcohol or ether as is often done in Germany. The carbolic acid has a wonderful power of penetrating grease or epidermis & if time be given for it to act it is unnecessary to wash off this grease beforehand. If the wound is to be made in the neighbourhood of hair, as the axilla or the putis the part must be well shaved & then soaked with

Soap & water &c not necessary

Errors in purification of the skin

the carbolic lotion.

The errors in the purification of the part may be that the skin is not purified at all, or it may be simply washed with water, or as I have seen[,] an operator allows a carbolic spray to play over it for a minute or so & is satisfied with this, or he rubs the surface with his wet finger. This purification must however be done thoroughly for in every hair follicle there are present numerous causes of putrefaction.

Purification of hands

At the same time the operator & his assistants purify their hands. This must also be done thoroughly & more especially the folds of the nail must be well cleaned out with the lotion. In an important operation, as in one on a joint[,] it is well to use 1-20 carbolic lotion for this purpose so as to avoid any change of a lurking particle but in ordinary cases 1-40 is quite sufficient. This purification of the hands is only too apt to be a sham[,] no care being taken about the nails &c. The 1-20 is not used in all cases because 1-40 is really sufficient & the stronger solution is apt to benumb the hand.

Purification of the instruments

The instruments are purified by immersion in 1-20 carbolic lotion before the operation. A porcelain trough which is filled with the 1-20 solution is used, & in this

Precautions

the instruments are placed some time before an operation. The instrument is not merely dipped, it must be washed because any grease & dirt which may be on it requires a little time for the carbolic acid to act. For the same reason, the teeth of toothed instruments ought to be cleaned thoroughly & any instruments locking by catches widely opened so as to let the acid come in contact with all parts. The whole instrument must be immersed for if only the point be purified it may be that the handle may inadvertently be brought in contact with the wound during the course of the operation.

Errors

*[Added in pencil] Thus I have often seen the blade of a scalpel alone purified & the surgeon in the middle of the operation use the unclean handle for tearing aside parts.

The errors most likely to occur are that during the excitement of an operation an instrument not previously in the tray may be used without purification or that the instrument may be imperfectly purified or only part of it cleaned. *Other errors in the manipulation of instruments will be referred to presently.

Spray

The spray is very important in many cases for it provides an atmosphere in which instruments may be kept without any contamination. In order to have a wide & large antiseptic area in which to move[,] the spray ought not to be too near, about 6 or 8 feet or more being the proper distance for a good spray. Care must be taken that the spray is not blown off the part by draughts of wind or by people moving about.

Distance from the operator

avoid draughts

This spray is most necessary in opening up abscesses or in stitching up wounds for, to take the latter case, as the wound is not syringed out after the stitching, if the spray be not over the ground all the time septic air may be enclosed in the cavity of the wound & may give rise to putrefaction.

Repurification of hands instruments &c.

During the course of an operation any instrument once purified & kept in the spray, though covered with blood remains pure & may be introduced into the wound without hesitation. The same is the case with the hands of the operator or assistant & therefore the dresser[,] in handing instruments to the surgeon[,] must hand them into the spray. If in the course of the operation the surgeon reaches his hand out of the spray for any purpose it must be repurified before being put into the wound. For this purpose there is generally a basin of 1-40 carbolic lotion placed close to the operator in which fingers instruments &c. are repurified by momentary dipping. When instruments are laid down out of the spray or in the spray on a blanket they must be repurified before being used again. To provide a basis on which instruments may be laid the wet towel is arranged before the operator as formerly described & the blankets in the neighbourhood are generally also covered up with wet towels so as to avoid the chance of the instruments being laid on the blankets. Should the

operator, during the course of an operation[,] wipe his hands in a dry towel or touch any unpurified substance he must remember to wash his hands in 1-40 carbolic lotion before reintroducing them into the wound.

The precautions on the one hand seem self evident while on the other they seem so burdensome to remember that they are often neglected by self-sufficient surgeons. And yet it is in the neglect of these rather than any other part of the Listerian method that mistakes arise and failures occur. Many people think that the spray is the essential part of the treatment & neglect the precautions as to constant purification of instruments &c & when their cases go wrong they say that the principle is incorrect and yet one thoroughly acquainted with the Listerian method will readily detect the loopholes. The general loophole is the omission of some of the precautions with regard to purification of fingers[,] instruments &c. Thus I have seen a surgeon, who has had considerable experience in aseptic treatment, during the course of a difficult operation wipe his hands with a dry towel & immediately introduce his hands covered with this dust into the wound [the word “wound” replaces the word “abdomen” which is struck through in pencil]. The patient [the word “patient” replaces the word “woman” which is struck through in pencil] died of septic poisoning. Now many surgeons might have said, I used the spray, I used

Most common errors in aseptic treatment

Too much trust placed in the spray

all precautions, my instruments were soaking, my hands were purified &c[,] forgetting this one little incident. When the error was pointed out the mistake was seen. [The previous sentence replaces the following which is struck through in pencil: *When I pointed out this error to the gentleman to whom I refer he at once saw the mistake & will no doubt be very careful in future against the occurrence of a similar accident.*]. People are too apt to trust in the spray as sufficient & to speak of aseptic or Listerian surgery as treatment by the spray. This is a terrible & often fatal mistake. Of all the precautions required by Mr. Lister that of purifying the air by means of a carbolic spray is the least necessary for there are but few septic particles present in the atmosphere & also if any fall on a wound they may be rendered inert by washing the wound with carbolic lotion. It must be remembered that Mr. Lister carried out aseptic treatment for years with great success without any spray & if at the present time he were compelled for any reason to give up some precaution he would at once throw aside the spray as the one which is least necessary & which could be the most readily dispensed with. At the same time the spray is an immense convenience in many cases[,] more especially in abscesses, empyæma, stitching up

{added in pencil] with the consequent irritation & risk of poisoning

Further errors

What is to be done when an error is detected at the time of its committal?

Impure instruments &c

Failure of spray

wounds &c. [added in pencil] & saves having to apply a great deal of carbolic acid to a wound.

To return to the errors which may arise in this part of the treatment. It may be that the spray is too near & that thus the cloud is so narrow that the surgeon is constantly getting his hands or his instruments out of it & forgetting to repurify them. Then instruments may be used which have never been purified, which have been only imperfectly purified, which have been only partially purified, which have after their use lain about outside the spray on blankets &c., or it may be that the carbolic acid gets exhausted in the spray bottle or that for some other reason the spray does not act properly.

What is to be done should any of these accidents occur? Suppose that an impure instrument or finger be introduced into the wound[,] that wound must be thoroughly washed out with 1-40 carbolic lotion. This is a bad thing for the wound because it irritates it & may prevent healing by first intention or by causing a much larger quantity of discharge than usual [-] the gauze may be unable to prevent the spread inwards of putrefaction. Therefore it is better to use the spray & to take all the precautions before mentioned. Should the spray stop[,] the wound must be washed out just as in the former case & then till the spray can be set agoing

again the wound is covered with a piece of rag soaked in carbolic lotion.

The Guard

This piece of rag called the Guard ought to be always present in the basin by the side of the surgeon & when there is any indication that the spray is failing or should it be advisable to stop the spray for any reason this is thrown over the wound for the time being. Should any time elapse before the spray is ready for use this guard must be repeatedly moistened with carbolic lotion. 1-40.

Ligature of vessels

The ligature of the arteries is accomplished by the use of catgut. This catgut is generally used of 3 different sizes. The larger is used only for large vessels, or for stitches, the medium sized used for medium vessels or for vessels in inflamed or dense tissue where considerable force is required to constrict the vessel, the small[,] a fine catgut[,] is that ordinarily employed for the smaller vessels. The vessel having been securely tied, the catgut is cut short & gives no more trouble. It is well to tie all visible bleeding points as a little oozing of blood may give trouble afterwards from tension. Should a vessel be situated in dense tissue, a needle carrying a double catgut thread should be passed through the tissue & tied on each side of the vessel. The catgut should be taken direct from a trough containing carbolic oil & should not be wet in the lotion. Where the

Number which ought to be tied.

Advantages of catgut in exceptional cases.

bleeding is from a tear in a large vein & when it would be dangerous to ligature it I have seen the following method adopted by Mr. Lister. In removing some cancerous glands from the axilla he made a longitudinal tear in the axillary vein. Taking a fine curved needle & the finest catgut he stitched up the tear with the glover's stitch. The patient recovered without the least bad symptom. There was no pain in the wound, no swelling of the arm &c. Then in another case where the longitudinal sinus was injured in trephining for epilepsy, the wound was plugged thoroughly with catgut & the patient recovered without the slightest bad symptom.

Drainage

Results of bad drainage

The drainage of an aseptic wound is the point next in importance to keeping the wound aseptic. For if the blood & serum which collect in the interior of the wound within the first 24 or 48 hours do not get free they give rise to tension, followed by inflammation, & if later allowed to go on long enough, suppuration, & thus the rapid healing of the wound is prevented though in general[?] the patient is not subjected to any risk. To avoid these consequences Mr. Lister has paid very special attention to the drainage of wounds. There are two main ways in which this may be done – drainage through tubes or drainage by capillarity. The former is the most universally applicable & the most certainly successful.

Two methods of drainage

Drainage by tubes

Kind of tube

The Holes in the tube

Length of tube.

Strings to retain it in position

Drainage by means of tubes is that first used by Mr. Lister & as just stated is the form of drainage which is most universally applicable. The tubes generally used are the indiarubber tubes introduced by Chassaignac though of late the kind of rubber has been altered; that now employed being red rubber which contains no free sulphur. By the use of these red rubber tubes smells & blackening of the protective, which often occurred when the black tubes containing free sulphur were employed, are avoided. These tubes have round holes cut in them at close distances[,] the holes being at least $\frac{1}{3}$ of the circumference of the tube in diameter. At the end the tubes are cut flush with the surface of the skin – straight across if the tube goes directly downwards, or with varying degrees of obliquity according to the direction which the tube takes. The tube must not project beyond the surface for if it does its orifice gets compressed by the dressing & the exit of fluid is prevented. To hinder the drainage tube from slipping in, two pieces of carbolised silk are fastened into it & tied in a knot. This knot catching in the dressing holds the tube. In some cases however[,] as for example in empyema[,] the tube may slip in spite of these threads & therefore it is well to fill up the loop with strips of gauze soaked in the carbolic lotion. These absolutely prevent the tube

Purification of the tubes

Size of tubes

Dependent position?

Rules to guide us in that respect

Number of tubes

from slipping in. These tubes are always kept in a stoppered bottle containing 1-20 carbolic acid & are thus always ready for use. When a tube is altogether removed from a wound it is not thrown away but it is washed & then put into the bottle with the other tubes & used for another case. These tubes are used of largish size & arranged so as to drain the parts of the wound which form cavities or from which most discharge is expected. It is not necessary that their orifices be dependent though it is of course better that they should be so. But it is not required because the fluid as it forms wells out &[,] not being putrid[,] that which lies at the bottom of the drainage tube does not cause irritation. In cases where the most dependent opening would be near sources of putrefaction it is well to have the drainage tube in another part not so dependent. Thus in inguinal hernia the tube would be in the most dependent part if its orifice were close to the pubis but as that would be much too near sources of putrefaction such as the vagina or penis the orifice of the tube ought to be at the upper angle of the wound. In a large wound it is well to have more than one tube & it is better to have two smallish tubes in any case rather than one large one because on the day after the operation one of these tubes may be removed while if one large one were pulled out there would [be] the greatest difficulty

First removal of tube

As to leaving out the tube.

Capillary drainage.

Catgut

Means of fixing the catgut

Size & number of bundles.

*A point which has always seemed to me of great importance in connection with the use of the tubes & one which has apparently been overlooked is the following: A tube is taken out of carbolic lotion[,] say some distance from the spray, is carried through the air & is then directly inserted into the wound. It was supposed that there would be sufficient vapour of carbolic acid in the tube to destroy any septic dust which might get into its interior. This I can hardly believe for if a large tube is taken out of the lotion a considerable mass of air takes the place of the fluid & this amount of hospital air will almost certainly contain causes of putrefaction as I have found by experiment. Of course when passing through the spray when introduced into the wound a considerable amount of this air would be displaced while at the same time there is a good deal of carbolic acid about & purification would probably occur while the purifying [continued in notes opposite page 190]

replacing it. No tube which one wishes to put back again should be removed till the 3^d day on account of the difficulty of returning it. By that time, however, it lies in a tube of blood clot or lymph & slips back easily. Generally on the 3^d day half the tube is cut off & it is reduced at subsequent dressings till it is no longer necessary. No exact rules can be given for leaving out the tube. This must simply be a matter of experience guided by the amount of discharge & the tendency to accumulation or otherwise. Should tension occur a larger & longer tube is at once introduced.

*Drainage by capillarity was introduced by Mr. John Chiene who was also the first to enunciate the principle of absorbable drains. For this purpose he uses catgut, generally the finest threads. A skein of catgut containing say 20 threads is tied at its middle by a piece of catgut. One end of this piece is passed through a needle & by means of this the catgut is stitched to the bottom of the wound. The skein is now broken up into bundles of 5 or 6 threads each. One bundle comes out at each angle of the incision & other bundles pass out at intervals between the stitches. More than one skein may be required in a large wound. This catgut becomes absorbed & never requires taking out. In 5 or 6 days

Advantages

[continued from opposite page 188] power of healthy tissues to be afterwards demonstrated must be taken into account. Nevertheless in the case of a cavity this may not happen & a case, which will be afterwards alluded to, of opening a knee joint in which inflamm. afterwards occurred to my mind receives no other feasible explanation. My suggestion is always to take the tubes out of the lotion in the spray & then the air which enters will be air purified by the spray.

Objections to the catgut drain

Since Mr. Lister has adopted this plan he thinks that his results are more absolutely pure & it is possible that this may be one of the sources of the micrococci which[,] as we shall afterwards see[,] are often present in wounds treated on the Listerian principle & which are very abundant in the hospital atmosphere.

Consideration of these objections

[Struck through] Mr. Lister thinks that the irritation occurring at later periods[?] is when dressings are left long on & which[?] I believe to be done to the min. ? less frequent. [Additional note in ink] When present they must interfere somewhat even though it be to a very slight extent with the typical course of a wound.

the ends which hang out drop off & little granulating sores are formed which heal in a few days. In this method the serum escapes by capillarity[,] & by distributing the threads over various parts of the wound the true principle of drainage is carried out. For as pointed out by Mr. Chiene[,] in draining a field one does not have one large drain going from one end of the field to the other. On the contrary the field is traversed by numerous small drains. And so in Chiene's method of draining of wounds we have a number of small drains traversing the wound in various directions. And here further there is no trouble about pulling out the drain & no necessity for changing the dressings simply to remove a tube – the drain disappears of itself.

The objections urged against this method are firstly that in large wounds it is not sufficient that the catgut becomes a pulpy mass, &, when in large quantity, takes a long time to organize. Not only may it be insufficient at first but it may drop off too soon – before indeed a drain of some kind can be dispensed with.

Now most of these objections rest on the fact that the drain is often imperfectly employed. If, for instance, it be not stitched to the deepest part of the wound the catgut slips & the deeper parts are not drained & again if a large bundle of it be used coming out

at one part of the wound only it does become pulpy & takes a long time to organise. But this is not the method recommended by Mr. Chiene. He says that only 5 or 6 threads ought to be brought out at each place. There is no doubt that in some cases it is absorbed too quickly. This may be avoided by preparing the catgut somewhat differently, & I hope a method will soon be published by means of which ... [unfinished sentence]. [Added in pencil] Mr. Lister's new method is nearly ready[?]. [end of addition]. Catgut cannot drain pus.

Horse hair drains.

advantages over catgut

Disadvantages

Instead of catgut horsehair has been a good deal used. This is simply laid into the wound in the situations where it seems most required. It is diminished by degrees, by taking out threads at various intervals. It has an advantage over catgut in draining joints, for no part of the drain remains in the interior of the joint while portions of catgut do. Further it is not absorbable. But it has the same disadvantages as the drainage tubes & it is not readily retained in the deeper parts of the wound. It is preferred by Mr. Lister to the catgut but there can be no doubt [The phrase *there can be no doubt* replaces the phrase *on this point I venture to differ very strongly from him*] that catgut used strictly according to Mr. Chiene's directions is a very efficient method of drainage.

Decalcified bone tubes

Of late this principle of absorbable drains has been applied by Dr. Neuber of Kiel in his absorbable drainage tubes. These are composed of decalcified bone hollowed out to

form a tube with holes [which] are cut like the ordinary indiarubber. They are said to answer very well though they take long to be absorbed. I have not tried them nor seen them tried.

Stitching up.

The accurate stitching of the wound is another feature in aseptic surgery. In operating aseptically the same care need not be taken to remove as little skin as must be done where inflamm. & swelling of the edges are expected. One may take a wide sweep, one which would seem to render hopeless any attempt to bring the edges of the wound into apposition & yet if the edges be only apposed & the wound remains aseptic union by first intention may be expected along the whole line.

Button stitches

[In pencil] See MacEwan[?] p.144

To relax the edges of the wound & thus to leave the cutaneous margins free from the irritation which must occur if they are tightly strapped together[,] Button Stitches are employed. These consist of flat pieces of lead cut of an oval form & of various sizes, perforated in the centre by a hole through which silver wire is passed & provided with two lateral flaps round which the wire is twisted. These are inserted some distance on each side of the wound & connected by strong silver wire drawn tight enough to permit of the edges of the wound coming pretty easily together. Several pairs are used according as there is necessity.

Stitches of relaxation

To bring the edges of the wound into actual contact two sets of stitches are employed. Silver

Stitches of coaptation

wire stitches which take a good hold of the tissues & are placed at regular intervals - termed stitches of relaxation [-] & in the intervals between these, in order to have the edges accurately applied to each other numerous stitches of coaptation consisting of carbolised silk[,] horsehair or catgut are inserted. The speedy healing which occurs when the edges of the wound are accurately coapted[,] while they are at the same time by the bottom stitches & the stitches of relaxation relieved of the tension necessary to bring them together[,] rewards the surgeon for the time spent in inserting a large number of stitches of coaptation.

Removal of these stitches

In taking out these stitches a reverse order to that of insertion is best. The first to be removed are the stitches of coaptation while probably the same day those of relaxation are cut. Do not be in a hurry to remove the stitches where there was much tension in bringing the edges of the wound together. A week or 10 days is time enough.

Dressing

Having proceeded thus far in the aseptic operation, having tied the vessels, arranged the drainage & brought the edges of the skin well together, we must now arrange a dressing which shall prevent the occurrence of putrefaction till the case is again seen.

Protective

Size & extent

And in applying a dressing we must be careful to make it as little irritating as possible to the line of incision & the newly forming epithelium. The dressing employed is the carbolic gauze while to prevent irritation of the healing edge of the wound by the carbolic acid a piece of protective is applied next the wound. This piece of protective is cut a little larger than the wound & it is well to cover the buttons with a little bit to prevent the threads of the gauze becoming entangled in them. This protective need not extend over the orifice of the drainage tube as its only use is to protect the healing part from the irritation of the carbolic acid.

Errors in use of protective

An error which is frequently made is to put on too large a piece of protective. There is nothing antiseptic in its substance & it protects the discharge beneath it from the action of the carbolic acid. Therefore if it at any part project beyond or close to the edge of the dressing it allows putrefaction to spread inwards beneath it & prevents the carbolic acid from acting on this putrefying discharge. It is therefore a very good rule having covered the wound with sufficient protective to look on this protective as a wound & to be as careful in having the gauze dressing overlap it in all directions as if it itself were the wounded surface. Where there is

Cases where protective cannot be used

very little space for overlapping, as in inguinal hernia, no protective ought to be applied. Better to have a somewhat slower healing than to have putrefaction spread into the wound. As mentioned before this protective is dipped in carbolic lotion 1-40 before being applied.

Wet gauze

Reason for wetting it.

Outside the protective a piece of Gauze wet in the carbolic lotion 1-40 is applied overlapping the protective in all directions. The reason for this is that dry gauze receives all sorts of dust before being used while at the ordinary temperature of the atmosphere but little carbolic acid is given off from the gauze, certainly not enough to destroy the activity of the septic particles in the dust. But if the piece of gauze applied next to the protective be moistened in the 1-40 solution this dust is destroyed & we apply over the wound a layer of puree & antiseptic gauze while before the discharge has time to reach or soak through dry gauze the heat of the body has disengaged enough carbolic acid from it to destroy these septic particles.

Deep dressing

The piece of wet gauze & the protective go by the name of the deep dressing. This deep dressing may in some cases & more especially where catgut stitches & catgut drains are used

Manipulation of deep dressing

Treatment where cut removed

It may be fixed down

Use of salicylic cream

Loose gauze for padding

be left for days undisturbed. In this way the wound is not irritated by the application of carbolic acid to it at each change of the dressing. If the deep dressing be thus left it must be remembered that the deep piece of gauze loses all its carbolic acid very soon & that therefore it must be treated as a wound & in renewing the dressing this deep part must be overlapped in all directions by a piece of wet gauze & that again by a dressing of suitable size. In some cases it may be desirable to fix down the deep dressing with a piece of gauze bandage. If it be intended to leave on this deep dressing for some time it is well before applying it to rub the neighbourhood of the wound with the salicylic cream mentioned before. It sometimes happens that when a dressing is left on for many days together the discharge becomes somewhat irritating & the skin around the wound becomes excoriated. This is generally entirely prevented by the use of salicylic cream.

Having arranged the deep dressing in a suitable manner any hollows which exist in the neighbourhood of the wound are filled up with carbolic gauze & special masses of this material are placed where the greatest amount of discharge is expected. Outside this a large gauze dressing made as before described is

Outer dressing. Size.

applied. The size of this dressing varies according to the amount of discharge expected but in all cases it must extend well beyond the deep dressing in all directions. Some special examples will be mentioned presently.

Fixing of dressing.

This dressing is fixed with a gauze bandage. This gauze bandage is preferable to an ordinary bandage for the following reasons: It is lighter & easier of application. It is cheaper. If desired it can be used next the wound as in bandaging a stump or fastening down a deep dressing. Should discharge escape from beneath the dressing or through a hole in the mackintosh it meets with an antiseptic layer & thus does not so readily putrefy. The dressing is pinned round its edge to this bandage. Care must be taken not to put pins through the mackintosh at any part except at its edge. Pinholes through the centre of the mackintosh simply defeat its object by permitting the discharge to come directly through the dressing. The object of the mackintosh is to make the discharge travel through large extent of the gauze & thus the same result is obtained as if a mass of gauze were applied over the wound of the same thickness as the distance from the centre of the mackintosh

Advantages of a gauze bandage

Application of pins

Use of mackintosh

Care as to holes in mackintosh

*[Added in pencil] It is well to sponge the mackintosh with 1-20 lotion before placing it in the dressing. The same piece of mackintosh may be used for a whole case or for more than one, so long in fact as it does not become worn into holes. 2 mack. are generally provided for each case, & a dressing is always made immediately after the last dressing & is ready for application at any time.

Elastic bandage

Salicylic Jute.

Application of elastic bandage.

Chiefly used in ? [Cheyne's question-mark]

to its edge. If therefore there be a pinhole near the centre of the mackintosh the object of the latter is completely defeated. Accordingly it is always the duty of the person who makes the dressings to examine the mackintosh with the view of detecting any holes which might render it useless.*

It may happen that in the movements of the patient the edge of the dressing becomes separated from the skin & air passes into the space thus formed. To prevent this the German surgeons as a rule pack in salicylic jute or wool round the edge of the dressing. This may serve the purpose but it is by no means safe. Mr. Lister some time ago introduced the use of an elastic bandage applied around the edges of the dressing. This bandage is white cotton elastic bandage which is used of various breadths. It is better not to be too broad. It is put moderately on the stretch & surrounds the edge of the dressing. Its general arrangement varies of course with the situation. It is not much used in the extremities, generally the arm or leg is so fixed that there is no chance of separation of the dressing[,] more especially in the leg where a splint is often applied to keep the wound at rest.

When should the dressing be changed?
First dressing

The operation & first dressing having now been completed the question arises when the dressing should be next changed. It is only extremely rarely that it is necessary to change it the same evening. The only cases in which this is normally done are large empyemata or very large abscesses, & amputation at the hip joint (sometimes) where there is but little space for overlapping of the dressing.

After the first dressing

As a rule the dressing ought to be changed entirely on the following day, deep as well as superficial. It is well to change the deep to see that none of [the] stitches are too tight & that the drains are acting properly. After the first day the deep dressing need not be touched unless the patient is complaining of uneasiness or unless the surgeon wishes to see the wound for the purpose of removing stitches or drain. If it is not necessary to disturb it[,] it is better not to do so for that would only be to expose the wound unnecessarily to the irritation of the carbolic acid.

Mode of changing the dressing

Removal of the old dressing

In changing the dressing we use the spray & 1-40 carbolic lotion in which a piece of loose gauze & protective are put to soak before the dressing is begun. The elastic bandage is first removed & then the patient or an assistant places his hand over the centre of the dressing while the bandage is being cut so as to prevent the dressing being lifted & air being pumped

Application of fresh

Washing.

*[Added in pencil] It is well to apply the deep dressing at once for in washing the surrounding parts one is apt to give the wound a final touch with the rag. Now this rag may contain some gross particles of

Rule for changing the dressings in future

putrid material (such as a crust of discharge from outside the dressing & faeces &c) & thus putrefact. would be communicated to the wound. There is no necessity for cleaning the edges of the wound. Dirt[,] so long as it is clean[,] i.e. as it does not contain causes of putrefaction[,] does no harm, indeed it rather aids the action of the protective while to rub it away is to injure the healing edges & to produce a state of Unrest.

Never left longer than 8 days

in. Then the surgeon having purified his fingers & having turned on the spray lifts the edge of the dressing carefully[,] taking care that the spray passes into the angle between the dressing & the skin. Having removed the superficial dressing he again dips his fingers & then removes the deeper parts & exposes the wound. If nothing is wrong he immediately applies fresh protective & wet gauze & then washes the parts round about as far as the discharge has extended.* Therefore the edge of the wound is not washed & is not exposed to the action of the spray longer than is absolutely necessary. A fresh dressing is then applied as before.

The next dressing takes place the following day at visit if there is any discharge at the edge or if the wound feels uneasy. If there is no discharge on the drawsheet & if the wound is comfortable the dressing is not changed & even though discharge should appear a few hours later the dressing is not changed till next day at visit hour. The rule for changing the dressing is then[:] Change if discharge is through at the visit hour or if there be any other reason for it. If not, leave it till next day at visit & then follow the same rule.

However never leave a dressing longer

Why?

than 8 days unchanged. By that time all the carbolic acid has passed off, having evaporated owing to the heat of the body & therefore if the discharge once came to the edge putrefaction could spread inwards with great facility. And it would not be necessary for the discharge to appear at the edge in order to have putrefaction of the wound, for the sweat collecting beneath the dressing permits the multiplication of putrid particles in it & thus they may reach the wound. Where a dressing is to be left on a week it is well to use the salicylic cream as mentioned before.

Boracic dressings

Such is the general method of using carbolic dressings – special modifications will be noticed presently. Let me pass on in the mean time to the general points as to Boracic dressings.

Foul ulcer taken as example

Let us suppose that a patient is admitted with a foul ulcer of the leg, how is he to be treated? If he were to be treated with carbolic dressings the ulcer would very probably remain foul or if ultimately it became sweet it would heal excessively slowly. Hence Mr. Lister first purifies the sore & then dresses it with boracic acid.

Purification of sore

To purify the sore Chloride of zinc 40 grs. to oz. of water is used. This is applied on lint thoroughly to the whole surface of the sore [struck through: & *rubbed well in*].

Purification of the surrounding skin.

Dressing.

Iodoform used instead of chloride of zinc

Changing of the dressing.

When necessary.

Way?

At the same time the surrounding skin is well purified by a thorough washing with carbolic lotion. When this has been done a piece of protective, dipped in boracic lotion, slightly larger than the sore is applied over it & outside this a layer or two of moist or dry (it doesn't much matter which) boracic lint is fastened, covering the protective well in all directions. There is the same objection here to allowing the protective to project as in the former case. Lately, instead of applying the chloride of zinc solution which causes great pain, iodoform has been used powdered over the whole surface of the ulcer & it has been equally successful. The chloride of zinc or the iodoform need only be applied once but should putrefaction not be eradicated the application is repeated.

The dressing is changed next day but afterwards boracic dressing does not require changing for some 2 or 3 days or indeed longer provided there is not much discharge. I mean to say that there is a very large store of the antiseptic in the lint & as it is but slightly soluble in fluids at the temperature of the human body, the discharge may go through the dressing many times without washing out all the antiseptic. At the same time it is found that the quickest healing is obtained when the dressing

Method of changing the dressing.

is changed once in 3 days.

At the changing of the dressing no spray is required. The bandage (which may be a common cotton bandage if preferred) having been removed[,] the dressing is taken off & the wound well washed with boracic lotion. Any dust which falls on the wound during its exposure is destroyed by giving the wound a final wash before applying a fresh piece of protective & boracic lint.

Boracic ointment. When necessary?

This boracic dressing is not used for wound[s] which are not quite superficial because the acid is not volatile & because it is but a feeble antiseptic but when once a wound has become quite superficial it will heal more quickly if treated with boracic acid dressing.

Conditions in which Boracic dressings are employed.

[Added in pencil] Of late, salicylic ointment has been used & has been found to answer as a rule better than the Boracic. It is less irritating & permits healing more readily.

In some cases, more especially where there is a hollow which with the protective would form a cavity, boracic ointment is preferable & where the sore is healing the half strength is the best. Outside the ointment a piece of boracic lint is applied as usual.

I shall now proceed to point out the methods of dressing employed in different localities of the body but first I must mention one or two general points.

Antiseptic strapping

*[Added in pencil] Should the wound gape[,] strapping may be used even under an antiseptic dressing. To render the strapping aseptic it is immersed in warm carbolic lotion (one part of 1-20 carb. lotion & an equal part of boiling water) before being applied. This both renders it aseptic & also takes the place of the hot water can for heating the strapping.

As to bringing edges together by tight stitching

Protection of part of a large wound during dressing

Wounds near sources of putrefaction**Special methods in different situations**

Scalp.

Hair shaved.

I have already stated on the one hand that where required one need not save skin & indeed a superfluity of skin[,] instead of being as formerly a good thing[,] is rather a nuisance from some of the folds interfering with free drainage. While on the other hand I have pointed out how by careful stitching many margins of skin may be brought together which were at first sight apparently hopelessly apart[,] while even after part stitching healing occurs readily.*

Where the wound is very large it may be protected during the operation either by having two sprays or by covering up the part of the wound which is not being operated on by means of a guard.

Where [there are] 2 wounds on opposite sides of body, then I have mentioned how, when the wound was near sources of putrefaction, the drainage ought to be carried on from the furthest end while no protective should be used.

Special Methods of Dressing & other precautions in different situations.

In operating on the scalp the hair must be shaved for some distance in the neighbourhood of the wound & the hair beyond ought to be soaked with carbolic lotion 1-20. If the incision be in the centre of the scalp or in other words if there be a circle of hair all round[,] it is better

not to use protective at all. The arrangement of the dressing on the centre of the head is the ordinary cap or fine bandage. When the wound is more or less to the side the dressing must extend downwards on the neck & it is then well to have a narrow elastic bandage along the edges, more especially around the neck. In the neighbourhood of the ears the various cavities in the ear & the space behind it must be filled up with gauze. There must not be any space in the interior of a dressing filled with septic air.

Neck dressings.

Neck dressings have nothing very unusual about them. The dressing must be fastened round the neck. It must be prevented from slipping down by a turn over the ears & around the forehead & if necessary 2 vertical turns – one transverse & one longitudinal, all these being pinned together. It must not slip up, this being avoided by turns passed under the axillæ. Elastic bandage must go round the edges.

Dressings applied to the neck are extremely difficult to retain in position though this can be done by a little careful attention. In this situation an elastic bandage nicely arranged around the edges of the dressing is of special advantage as the movements of the head are extremely apt to cause an interval between the skin & the dressing.

Breast dressings

In abscess of mamma

Breast dressings are very important. They are arranged in 3 different ways according to the size & extent of the wound.

Where an abscess of the mamma is opened or some small incision & one not interfering with the form of the organ is made, the dressing consists of an ordinary gauze dressing covering the whole mamma[,] some loose gauze being packed in behind. This is fixed by bandaging above & below the organ while the arm is placed in a sling. The edges are as far as possible fixed by elastic.

In excision of the mamma alone

Where the mamma has been alone removed, the incision not extending back to the axilla, there remains enough of room between the wound & the axilla for overlapping of dressing. In order to fix the dressing & get more room for overlapping, it is split at the axilla & folds over & is pinned on the top of the shoulder. It is then bandaged securely & an elastic bandage applied round the edges.

In excision of the mamma & axillary glands where the wound extends to the outer wall of the axilla.

Where the mamma & axillary glands have been removed – where therefore the incision extends to the humeral[?] end of the axilla this arrangement is not sufficient for it does not leave sufficient room for overlapping. The arm must therefore be included in the dressing. This is accomplished most conveniently

in the following manner. [Note added above this line: *Rewrite*]. A large dressing is applied posteriorly[,] reaching back as far as the middle line & folding over the arm so as to touch the thorax in front – the arm being applied to the side. This dressing must be about 3 inches broader than the length of the upper arm from the top of the shoulder to the tip of the elbow so as to allow of a little overlapping which can be caught by the bandage. To prevent the internal condyle suffering from the pressure a large mass of gauze is applied behind the arm extending downwards almost to the condyloid region but not reaching quite so far. A mass of gauze is packed in between the arm & the side & in front filling up the angle between the arm & the thorax. A small anterior dressing is then applied narrower than the posterior, reaching as far forwards as the middle line & outwards to the upper arm, the edge of this dressing passing beneath the edge of the posterior. Thus the side of the patient is completely encased in a gauze dressing. This is very easily bandaged on. One turn of bandage passes round the body outside the arm; the next passes round the body below the arm, catching the portion of the dressing overhanging the elbow; the next passes round the body & over the top of the shoulder on the side operated on[,] thus catching the portion of the dressing projecting above

the shoulder, the bandage then passes down behind but parallel to the arm, turns round below the elbow, runs obliquely upwards to the top of the opposite shoulder then obliquely back again behind (thus fixing the upper angles of the dressing in front & behind) to the middle of the arm over which it passes obliquely to go under the wrist & end at the top of the shoulder (thus completing the fixing of the bandage to the arm & at the same time acting as a sling for the hand.) Pins are now inserted at all the necessary parts. The arm & dressing are fixed securely to the side by a binder of calico passing round the body below the axilla of the other side[,] passed up & pinned above the shoulder & below the elbow of the included arm. Thus perfect rest is procured & no elastic bandage is required. When the axillary portion is soundly cicatrized, if any other part remain unhealed, the breast dressing No.2. may be applied, the arm being simply supported in a sling.

Axillary dressing

An Axillary dressing must be attached partly to the chest & partly to the upper arm & fold over the top of the shoulder & requires an elastic bandage.

Dressings on extremities. Use of elastic!

Elastic is not as a rule required for dressings on the extremities. The limb operated on is generally on a splint for a few days, in order to procure

absolute rest till healing by first intention is complete. Thus the movements which it is the function of the elastic to neutralize are avoided & the constriction of the elastic is also avoided. With regard to this constriction the elastic need never be applied so tight as to produce oedema [-] indeed I have more than once seen oedema present before an operation, subside afterwards even though an elastic bandage was used. Where the patient is allowed to move the extremity, as when he is allowed to walk after a small operation on the lower extremity, an elastic bandage is absolutely necessary.

When allowed to walk elastic is necessary.

Dressing for Psoas abscess

The dressing required for psoas abscess opened above Poupart's ligament is one of the most important as well as one of the simplest illustrations of the method of applying the elastic bandage. I may say here with regard to this method of opening psoas abscess above Poupart's ligament that there are two reasons for choosing this situation. In the first place the old rule that these abscesses must not be opened early is now quite done away with & under strict aseptic treatment as soon as fluctuation is detected an operation is performed as if to tie the external iliac artery & the abscess is opened after a careful dissection. The sooner the abscess is opened the better[,] for the abscess cavity is thus less

Reasons for opening these abscesses above Poupart's ligaments.

in extent[;] also[,] so long as the pus is there it irritates & keeps up inflammation in the spine. This then is one reason why the opening leading into these abscesses is generally above Poupart's ligament. Another is that even supposing the abscess to be pointing in the thigh it ought to be opened as far as possible from sources of putrefaction & the most convenient place in this respect as well as the best for the attachment of a dressing is the neighbourhood of the anterior superior spine. I do not enter here into the surgery of these abscesses & I therefore do not enter into the reasons why. It is thought [added in pencil: *more especially by Mr. Chiene*] best to try to get at these from behind either by perforating the ala of the innominate bone or by getting at the pus above the crest.

Method of dressing.

The dressing applied in this situation extends from the middle line in front to the middle line behind. It reaches as high up as the lower border of the ribs & as low as about 3 in. below Poupart's ligament. Special masses of gauze are placed in the neighbourhood of the pubis which is also shaved on that side. The dressing is fastened on by a spica bandage with circular turns round the thigh & abdomen. The elastic is applied accurately to the edge. It begins[,] say[,] at the upper & anterior angle of the dressing,

Management of elastic

runs vertically downwards along the anterior edge [,] then passing back round the inner side of the thigh it encircles the thigh thus fixing the lower border, then it runs vertically upwards behind to the upper posterior angle then[,] being held there[,] it curves & encircles the abdomen. The two ends are then attached to the circular piece by pins & pins are applied to all the angles & along the edge where necessary. In some deformed persons shoulder straps are necessary to prevent the dressing from slipping down.

In Lumbar abscesses straps must pass over the shoulders to prevent the dressing slipping down & between the thighs to prevent it slipping up.

In Hip joint dressings the arrangement is much the same as in psoas abscesses except that they pass lower down & not quite so high up. As a long splint is generally in use an elastic bandage is unnecessary unless in children.

Where abscesses are opened near the top of the thigh on the inner side & are thus pretty near sources of putrefaction large masses of gauze must be applied between the orifice & the perineum & an elastic bandage carefully fastened along the upper edge.

In operations for hernia, varicocele & on the scrotum in the male there is one form of dressing

Precautions in Lumbar abscesses

Hip joint abscesses

Abscesses on inner side & upper part of the thigh.

Operations for hernia, varicocele &c.

No protective

Carbolic glycerine

Perineal[?] pad

Arrangement of bandage

applicable to all. In the first place no protective is used. Outside the wound the gauze[,] instead of being merely wet with carbolic lotion is steeped in 1-5 or in 1-10 glycerine solution of carbolic acid & this is wrapped around the penis & over the scrotum. This gauze sticks to the skin & does not become detached with the movements of the body while it is more powerfully antiseptic than the gauze alone. Then a mass of gauze is rolled into a ball & this is suspended in a long strip of gauze. The ball goes in the perineum behind the scrotum & the strip of gauze passes up in each groin. The hollows having been filled up with loose gauze[,] the general dressing is applied. Towards one side of this a hole is cut through which the penis is passed & keeps the dressing in position. The dressing passes over the scrotum & over the perineal pad & is fixed by a double spica bandage. The pad in the perineum is fixed by a St. Andrew's cross in the perineum. The elastic is applied in the form of a St. Andrew's Cross in the perineum & of a double spica. The bandages dressing & perineal pad are carefully pinned together.

The methods of managing excisions of joints, operations for ununited fractures &c in the

Excisions of joints &c.

Method for first few days.

Method later

Still later Plaster of Paris.

lower extremities is very important. Here perfect rest must as far as possible be combined with strict antiseptic treatment. For 2 or 3 days after an operation it is better simply to change the dressing by lifting the lint because there is generally a large amount of bloody & serous oozing at first. After this oozing has ceased the dressing is accomplished in the following manner. A Gooch's splint is padded above & below the situation of the wound[,] the part opposite the wound being left unpadded. The whole splint is covered with a piece of Mackintosh cloth & is firmly fixed behind the limb above & below the situation of the wound. Behind the wound masses of gauze of sufficient thickness are arranged transversely & superficial to the mackintosh. These pieces are 3 or 4 in number or more & they act as padding for the splinter at the same time as an antiseptic dressing. When the dressing is changed a piece of gauze is pinned to each of the old pieces & then[,] the old piece being pulled out[,] the new is pulled in & thus the limb is never left without support. Another way in which this may be managed with even less movement is to have each mass of gauze divided in the middle line & thus the half of each mass is pulled out at a time & a new piece substituted.

[Added note: *Wire splint*] When the discharge becomes still less the limb may be put up in Plaster of Paris[,]

Excision of joints is rarely performed.

*[note added in pencil] It should have been mentioned that Knowsley Thornton in ovariectomy cases does not apply the bandage round the abdomen. He fastens the dressing with adhesive plaster & does not change it for a week by which time healing is generally complete except where the stitches are.

Antiseptic treatment of abscesses.

Situation of the opening

Chief points to be considered in its selection

a window being left for dressing.

Excision of joints is now very rarely performed. With aseptic treatment an incision into a joint & the insertion of a drainage tube is generally sufficient where formerly excision or even amputation would have been required. Several advantages are thus gained[,] among the most prominent of these being the fact that the limb is not shortened (& this is most important in children) & that there may often be a certain & even a considerable amount of movement in the joint afterwards.

*Such are the chief points as to the application of dressings. I must now say a few words as to the aseptic treatment of abscesses. I have already referred to the question of the necessity for a dependent opening & I pointed out that as the discharge from an abscess treated aseptically is not irritating, because not putrid, it does little harm even though left to well out instead of being permitted to flow out through a dependent opening. In fact aseptic surgery has altered the relative importance of the questions to be considered in selecting a situation for opening an abscess[,] and now the chief point to be considered is not whether the orifice of the tube is in the most dependent position possible but whether it is the furthest removed from sources of putrefaction – whether there is

greatest space for the overlapping of the antiseptic dressing. Indeed in some abscesses pointing near such canals as the pharynx, anus &c it is better to make an opening in healthy structures at some distance from the abscess & burrow a channel into it than to make an incision directly into the abscess cavity. I saw a striking example of this in Edinburgh several years ago. [This replaces a sentence which has been struck through: *A striking example of this occurred when I acted as House Surgeon to Mr. Lister in Edinburgh ...*] A boy was admitted with retropharyngeal abscess connected with occipito-atloidean disease. The abscess was on the point of bursting into the pharynx. Mr. John Chiene who had charge of the case[,] instead of opening the abscess at the only place where it was pointing – in the pharynx, cut down behind the sterno mastoid & burrowed into the abscess cavity from behind. The abscess followed a typical aseptic course & the patient recovered completely. Thus then the great rule in selecting a situation for opening abscesses is to open them as far from sources of putrefaction as possible.

As to squeezing of abscess

When opened, instead of dealing tenderly with the pyogenic membrane as was formerly done under the impression that it was a hurtful thing to injure it, we now squeeze the cavity to get out all curdy masses of pus &c which

may have gravitated to the bottom of the abscess. When this is done opportunity is given for the rapid adhesion of the greater part of the wall of the abscess cavity & thus in a very short time there is merely a sinus left leading down to the diseased bone.

No necessity for washing out the abscess cavity

Objections to it

There is no necessity for washing out the cavity of an abscess as is done in so many quarters. The pus contained in the abscess is as a rule irritating in the first instance & to inject carbolic acid into its cavity would be simply to irritate the pyogenic membrane without securing any good result. Indeed it might give rise to such an amount of oozing from the cavity as might wash out all the carbolic acid from the dressing in a very short time & thus lead to the putrefaction of the abscess. The treatment by hyperdistension[,] while absurd in theory[,] is very dangerous in practice as the fluid may get forced into the cellular tissue & lead to gangrene of that tissue with diffuse inflammation or to carbolic poisoning & death as I have known occur in more than one instance.

As to drainage

The greatest care must be taken in the drainage of these abscesses. In the case of a large psoas abscess the surgeon cannot introduce too large a drainage tube in the first instance. This tube may be changed for a smaller in a few days. It ought not to be

Tubes without holes.

No protective required

removed for the first time after the abscess is opened till at least 3 days have elapsed otherwise there may be great difficulty in replacing it. It should not be shortened till it is found impossible to get it in fully. Wherever it is evident that it projects it must be shortened. (Here I speak of chronic abscesses. An acute abscess heals in a week or 10 days). In some cases where the same tube is left in for a week (where the case is only dressed once a week) some difficulty will be found in withdrawing it owing to the granulations having grown in at the holes & holding it in position. In this instance the guide as to shortening is lost because the tube cannot be pushed out & therefore it will be found best in old cases to use a tube having no holes laterally. This cannot be held & is gradually pushed out as the sinus heals from the bottom. If on removal of a tube the discharge is found to increase in quantity the tube must be reintroduced.

As the incision into the abscess is merely large enough to admit the tube there would be no reason for using protective & therefore the wet gauze is applied directly over the orifice of the tube. A tube is the only form of drainage suitable in these cases.

Continue the same care till the abscess has healed

*[Added in pencil] Whether this rule may not be modified by the use of Sayer's jacket or even without it is now a question. In 2 cases which had been under treatment for a long time & in which all uneasiness in the spine had passed off Mr. Lister allowed the patients to get up before healing was complete without any bad result.

Metallic tube in Empyema

Cases where the ordinary method must be modified

In changing the dressings the same rules are to be followed as were formerly described in regard to incised wounds. Chronic abscesses, more especially spinal abscesses, are extremely tedious but nevertheless as a rule they ultimately recover. The same care must however be taken from first to last. It is never safe to change the carbolic dressing for a boracic one however superficial the wound appears to be. In the case of spinal abscesses absolute rest in the recumbent posture* must be maintained till complete healing & as these cases generally extend over many months it is well to warn the patient & friends before commencing to treat the case.

Empyema does particularly well under this dressing. I mention it here in order to state that a metallic drainage tube with a shield like a tracheotomy tube is the best because the indiarubber tube may get compressed between the ribs or too abruptly bent when it gets into the interior of the pleural cavity.

There are some cases in which neither the gauze dressing nor the boracic can be employed with advantage but which may never-

... theless be treated aseptically. I refer especially to abscesses in the perineum or by the side of the anus.

Abscess in the perineum

Abscess in the perineum may be treated aseptically with extremely satisfactory results. The abscess is opened under the spray & a piece of lint dipped in 1-5 carbolic oil or glycerine is introduced into the cavity to act as a drain. Outside this are applied 2 or 3 layers of carbolic oiled or carbolated glycerine lint which are fixed with a bandage. Should this become displaced or wet with urine &c. the patient pours a little carbolic oil or glycerine over the wound & over the lint. No spray is required in changing the dressings. On the 3^d day a piece of lint dipped in carbolic oil is laid over the wound, a pair of oiled forceps are slipped under the lint &[,] seizing the plug[,] it is withdrawn. 1-10 oil is then used for dressing & after a day or two boracic ointment.

Abscess in ischiorectal fossa

The same method of dressing is employed in the case of abscesses beside the anus. Here when the patient defacates he holds aside the dressing, defacates past it, wipes the parts with 1-20 lotion & then with 1-10 carbolic oil, soaks the dressing with the oil or applies a new dressing. (Glycerine may also be used). The results of this [sic] methods of treating these abscesses are often excellent, fistula in

ano being apparently avoided when the abscess is taken in time.

Accidental wounds

Problem.

So much for wounds made by the surgeon - & their treatment. I now come to the treatment of wounds produced accidentally. Here the problem is different from & much more difficult than the former. In the case we have just been considering we had merely to keep out the septic particles; in the present instance these particles have already gained admission & therefore we have not only to prevent the entrance of more but also to destroy those already present.

Method. Wash out the wound

This is done by washing out the wound with 1-20 carbolic lotion[,] provided it be recent i.e. 24 hours before being seen - & then treating it like a wound made by a surgeon.

This washing out of the wound must be done very thoroughly. It is best carried out by using a syringe with a catheter attached to it. The point of the catheter being introduced into all the recesses of the wound[,] the 1-20 is injected & thus comes thoroughly in contact with all parts. There must be no attempt to distend the cavity as for instance by shutting the orifice of the wound around the syringe for the fluid might be forced into the cellular tissue

* {Added note] This injection & the subsequent procedures are carried out under the spray.

If made 24 or 48 hours before being seen.

As to stitches

Where much contusion

& lead to sloughing &c. The opening must be left perfectly free & enlarged if necessary. Should there be any shreds of tissue they had better be cut off & if there be much dirt ground into the tissue it must be got rid of by means of a nail brush.* If the wound was made 24 to 48 hours before being seen a stronger solution is employed viz. the 1-5 spirituous solution. This is used in the same way as the other.

Having got the wound purified the question of stitching it up arises. The answer to this question varies according to the parts injured. As a rule in injury of the soft parts a drain is introduced & the same accurate stitching employed under the spray as described in a former page. More especially is this the rule in scalp wounds where most brilliant results may be obtained by the use of catgut drains & accurate stitching.

The rest of the treatment is the same as in operation wounds.

Where the wound is much contused the same rules apply as to purification, but it cannot be stitched up. After purification a large piece of protective is applied & the wound treated as usual.

I have mentioned the methods to be em-

Treatment where putrefaction already exists

1-5 carbolic oil

Special wounds.

Compound fractures

remove blood clots

Injection of the lotion

No stitches *[Added note] Another method of putting up a part[?] is by wire splint

Wounds of tendons, abscesses &c.

-ployed when the wound is seen within the first 48 hours. It may be however that it comes under notice somewhat later when putrefaction already exists. In this case it may be purified[,] if superficial[,] by stuffing it thoroughly with lint dipped in 1-5 carbolic oil. This dressing repeated for several days generally converts it into an aseptic wound.

Certain special wounds call for attention. Compound fractures are the wounds in which this treatment was first applied & in which excellent results may be obtained. There are a few special points. In purifying these wounds great pains must be taken. Any dirt must be carefully scraped or scrubbed out. All blood clots ought to be turned out as completely as possible. The ends of the bones are cleaned & if they can not be returned or got to fit[,] portions may be sawn off. The ends may even be tied together by silver wire. The parts ought to be well kneaded, while injecting the carbolic lotion through the catheter, in order to diffuse the lotion as much as possible into all the recesses of the wound. *The same sort of dressing is employed as for excisions. No stitches are inserted but on the contrary free drainage by tubes is used.

Wounds involving tendons[,] nerves or muscles ought to be treated in the same manner as others & the

ends of the divided muscles, tendons or nerves ought to be stitched together by catgut & the position of the part so arranged as to avoid dragging on these stitches.

Wounds of joints

washing out

drain

Passive motion

Wounds of joints are very important. When seen recently no operation (excision or amputation) is required in the first instance. As a rule the joint may be saved & perfect movement obtained by washing them very thoroughly out with carbolic lotion 1-20. The wound in the joint is enlarged, the spirituous solution is employed where several hours have elapsed since the accident (more than 8 or 10h.) A drainage tube is introduced into the joint but no stitches are used. After a few days when the discharge has diminished the drain is removed. In 3 weeks at least passive motion ought to be begun otherwise the adhesions outside the joint may require breaking down under chloroform.

Compound fractures of the skull

Compound fractures of the skull are treated as compound fractures elsewhere, purification being attempted with 1-20 carbolic lotion. The dura mater may be freely dealt with without fear, for the irritation of carbolic acid is only very transient. Any vessels are secured with catgut. Should one of the great sinuses be bleeding a graduated compress of catgut arrests it without danger. This I have known act very well in a case of wound of the longitudinal sinus occurring during an operation

Wounds of the thoracic cavity

of trephining over the seat of old injury in a case of epilepsy.

Wounds of the thorax are much more difficult to treat. Should the wound penetrate the lung & should the lung protrude, the exposed parts & those around are as far as possible purified by carbolic lotion 1-20. Where the lung is not wounded the external wound only is purified & is closely stitched in the hope that union by first intention may occur, that the air may be absorbed, & that any septic dust present in the pleural cavity may be unable to cause mischief.

Wounds of the abdomen. where no protrusion

Wounds of the abdomen are variously treated according as there is or is not protrusion of the contents. Where there is no protrusion & where there is no reason to suspect injury of the viscera the external wound is purified & closely stitched so as to get primary union throughout – no drain being used.

Protrusion of omentum

*{Added in pencil] When it can be returned[,] do so & then stitch the abdominal walls including peritoneum closely together. Where this cannot be done, [?] on a research &c.

Where the omentum protrudes opinions vary as to the treatment. From a research * into the consequences of unreturned omentum by Dr. Kenneth McLeod of Calcutta I should consider it the safest practice in the case of a person with strong muscular walls to purify the protruded portion of the omentum[,] to stitch the deepest part to the deep part of the wound, cut off the rest of the omentum [,] & close the skin over all.

Protrusion of intestines

If injured

If internal hemorrhage

Where (first) the intestines protrude they ought to be carefully bathed in warm carbolic lotion 1-30 or even 1-20 & if there be no injury of them in any part they may be returned. If they are cut the cut may be stitched up with the glover's suture in catgut.

If internal hemorrhage is going on the wound ought to be enlarged & the bleeding point sought for. Simon advised that in bleeding from one kidney that kidney ought to be excised. This suggestion was never put into practice but nevertheless it is one well worth bearing in mind.

Treatment of Putrid Sinuses

Scraping with sharp spoon

Chloride of zinc

Such are the chief points to be attended to in recent wounds. A certain class of cases, where putrefaction has been present for a long time, remains to be considered. I mean cases of putrid sinuses generally connected with diseased bones or joints. An attempt may be made to purify these during the course of any operation & sometimes when the sinuses are few & uncomplicated & where all the dead bone is removed this attempt may be successful. It is best done under the spray. The sinus is scraped out with one of Volkmann's sharp spoons & all the granulation tissue as far as possible removed. The raw surface of the sinus &c is then thoroughly washed out with chloride of zinc applied well to all parts & an antiseptic dressing applied in the

Subsequent treatment

Burns

Purification

Dressing where burn is small

when larger

*{Note added in ink] Wet boracic dressing is also applied in those cases where, on account of the extent of the burnt surface & the amount of dirt, purification with carbolic acid is not advisable.

where complete charring

Objections to carbolic oil.

hope that putrefaction has thus been eradicated. If it is so well & good. If not boracic ointment (at first full strength afterwards half) or salicylic ointment covered with boracic lint is the best dressing, indeed it is the best dressing in all cases where strict antiseptic measures are inapplicable.

The aseptic treatment of Burns varies according to the degree & extent of the injury. In any case unless where the burn is very extensive & where the part is extremely dirty (& also risk of carbolic poisoning) an attempt should be made to purify the surface with 1-20 carbolic lotion. This having been done[,] if the surface is small[,] boracic ointment (full strength) & boracic lint is a convenient dressing. When the extent of the burn is greater, wet boracic dressing is the most suitable (wet boracic dressing is wet boracic lint used as water dressing – covered by gutta percha tissue or by mackintosh. *Where the surface is thoroughly charred & where the wound is not very extensive boracic ointment or carbolic oil 1-10 are the best dressings. The objection to carbolic oil, which was formerly used in all cases[,] is that when the surface is large there may be a fatal absorption of carbolic acid. In the after treatment the wounds are dressed with boracic dressings (protective & boracic lint or better in the first instance boracic ointment) just as in

Treatment of gangrene

Senile gangrene

Purification

Carbolised cotton wool dressing

Length of time between dressings.

Different course from that ordinarily run.

Reason for this

the case of ulcers.

The rules as to the treatment of gangrene are altered in aseptic surgery & this is more especially the case in senile gangrene. Should symptoms of senile gangrene set in, say in the lower extremity, the skin of the foot, toes & leg are thoroughly cleansed with 1-20 carbolic lotion. This must be done very efficiently. All the folds about the nails &c must be carefully cleaned & washed. This having been done the whole limb & foot are enveloped in a large mass of carbolised cotton wool (carbolised in a 1 p.c. ethereal solution of carbolic acid). This being pure in its substance & being applied over a pure surface completely shuts out causes of putrefaction. The carbolic acid soon flies off & then the cotton wool acts simply as a filter while it protects the part from unequal pressure & retains the heat. This may be retained for any length of time &, so long as the discharge does not extend to the surface or the gangrene above the limits of the dressing, the part remains sweet & very often the gangrene, which in the first instance threatened to involve the whole leg, becomes limited & there may even be a small cutaneous slough. In any case as a rule the gangrene does not go on spreading as when treated in the usual manner, & for this reason: Suppose that the part is not treated aseptically,

the tissue at the edge of the dried gangrenous mass becomes putrid, the living tissue in the neighbourhood is very weak, the caustic putrid material destroys its vitality [Added in pencil: *or excites an inflam. which kills it.*] & so the gangrene goes on spreading till at length parts are met with of insufficient vitality to resist this action of the putrid materials. Then a line of demarcation is formed. Now when the dead parts are not putrid the weak parts in the vicinity, which would to a certainty have died in the former case, retain their vitality & gain strength. Thus also the rule of never amputating in cases of senile gangrene, except to trim a stump formed naturally, is done away & it is generally better to amputate when one is certain how much tissue is finally dead than subject the patient to the continual pain & irritation arising from the presence of the dead piece. The same reasoning applies to cases of traumatic spreading gangrene. This is only one instance of how completely many current ideas as to surgical pathology & treatment are reversed when means are taken to render the dust of the atmosphere inert before it reaches a wound.

In treating nævi great benefit will be obtained from the use of pure carbolic acid injected into them. The nævus is first thoroughly cut off from the circulation by ligatures tightly applied around its base & then half minims of pure carbolic acid are injected into various

parts of the tumour. Ten minutes having been allowed to pass, in order to ensure complete & firm coagulation, the ligatures are divided & removed & the punctures are touched with collodion. The surface being left completely dry[,] any slough which forms becomes absorbed or separates as a crust after some time, the part beneath being found to be a scar.

The same method answers excellently in the treatment of varicose veins. A tourniquet having been firmly applied above, the vein is punctured at various parts & half minims of carbolic acid are introduced.* Coagulation & a slight degree of inflammation are thus induced but this, so far as I have seen, never goes to any dangerous extent & is followed by at least temporary cure (I have never known any case return with re-formation of varicose veins, though this would be, of course, quite possible[]).

A dissection or postmortem wound does not give rise to bad results if the wound be instantly purified with 1-20 carbolic acid solution.

Such are the methods usually employed in the Listerian treatment in hospital or in private practice. It is however said to be difficult of application to country practice & we must therefore enquire in what way it can be made easier. The difficulties urged are that the spray is too heavy to carry, that it is not always easy to return

Treatment of varicose veins

*[Added note in ink] The tourniquet is removed 10 minutes after the injection is completed.

Poisoned wound.

Application of aseptic treatment to country practice

Objections

a long distance to see a patient on the day after an operation, & that the dressings are too expensive for the lower classes. We must therefore in some way or other render the dressings very infrequent so as to avoid expense & unnecessary visits & we must try to dispense with the spray. The putty is the better & would suffice.

Answer to these objections & methods for getting over them

When no spray what is to be done during an operation?

In the first instance[,] in going to perform an operation or to treat a wound, the surgeon takes instruments with him & he may without any additional trouble easily add a spray to the contents of his bag & this spray may be left at the patient's house & brought home again after the first dressing. But suppose the surgeon has not a spray at hand. What is to be done? Well he must proceed as described before by washing out his wound frequently during the operation & during the stitching up & before applying the piece of wet gauze he distends the wound with carbolic lotion &, while this is still flowing out, the wet gauze is applied. At the same time I cannot see that, in the great majority of cases, it can be any great hardship to carry a spray to an operation.

How to dress without a spray

During the after treatment a spray is not necessary. In two ways this is rendered unnecessary. In the case where catgut stitches & catgut drains are used a deep dressing may be applied at the time of the operation & never require changing afterwards. This deep dressing is fixed down in some way or other & is treated as a wound[,]

If deep dressing must be removed

Where a tube is used

To remove the tube

the gauze being soaked with carbolic lotion every time the superficial dressing is removed & then a piece of wet gauze & the general dressing applied. Should it be necessary to remove the deep dressing, there is no necessity for a spray if catgut drains be used because there is no cavity into which air may pass. The deep dressing having been removed, in this latter instance, carbolic lotion is allowed to flow over the wound till a guard is applied. Where a tube is used it is more difficult to do without the spray for there is an open cavity into which dust may fall & be sucked into the interior of the wound & further when the tube is removed air must enter to take its place. This may be avoided by the use of a syringe which constantly keeps a stream of carbolic lotion passing over the wound & over the drainage tube till a fresh dressing is applied. Should it be necessary to remove the tube[,] it is well in addition to this constant flow of lotion to cover the orifice of the tube. The best way is to take a guard soaked in carbolic lotion & folded in several layers[,] & place this over the orifice of the drainage tube, extending on each side for a considerable distance. The tube is now seized with a pair of forceps through this rag & as it is pulled out the rag is carefully tucked in around it, so as to compel the air as it passes in to take the place

To take out stitches

of the drainage tube to traverse this moist guard. This seems to me better than the method of slipping in forceps under the guard & pulling out the tube – the guard being well pressed down on it. In taking out stitches, if wire or silk has been used, the guard is pulled aside so as to explore the stitch – a little carbolic lotion is dropped over the suture & as it is withdrawn a few drops of carbolic lotion are applied to the orifice.

To render the dressings less frequent

These methods – the use of catgut stitches & catgut drain & the employment of a permanent deep dressing together with the lints in case a drainage tube or non-absorbable stitches are employed – suffice to render the operation independent of a spray. Can we now render the dressings less frequent? By applying a larger amount of gauze this may of course be done but the best way is to use sponges in the interior of the dressing for the purpose of absorbing & retaining the fluid. The deep dressing having been applied & fixed, a large sponge or several small ones are placed outside it, these sponges having just been wrung out of carbolic lotion. Outside the sponges & extending well beyond them is placed a piece of wet gauze & then the masses of loose gauze & general gauze dressing.

Use of sponges in the dressing

In this way the discharge is retained in the interior of the dressing & of course so long as it is there & so long as the discharge has not reached the edge of the dressing, it is as safe from putrefaction as if it were in a pure flask. By the use of these sponges several days may be allowed to elapse before the first dressing in many cases. When the dressing is changed these sponges are squeezed thoroughly, washed in carbolic lotion 1-40 & reapplied. By the use of these sponges 2 or 3 suffices [sic] for the treatment of most operated cases.

By use of Salicylic Jute.

By the use of salicylic jute in large masses the same avoidance of frequent dressing may be obtained but this jute is not very trustworthy as an antiseptic.

or cotton wool.

Thoroughly purified cotton wool, which may be obtained cheaply by impregnating it with sulphurous acid fumes, applied in large mass prevents the necessity of frequent dressing.

By the means described the difficulties in the way of the adoption of this system in country practice may be overcome. And instead of causing additional expense to a poor patient it saves expense in many ways. The dressings required are so few that the price of the materials employed is not greater than that which would be necessary even if water

dressings were used. And in many other ways, as I shall mention at the end of this paper, expense is saved notably in the more rapid healing which is of course of the greatest consequence to the bread winner.

The question arises whether this treatment can be applied in war. This question has been answered in the affirmative by Dr. Reyher of [?] during the late Russo-Turkish campaign. His method was the following. Each soldier was provided with several tampons of salicylic cotton or jute contained in a piece of salicylic gauze. As soon as a wound is made this tampon is immediately pushed into it without any preliminary probing or examination. The salicylic acid in the tampon dissolves in the blood, mixes with it & gets into the interior of the wound & is thus supposed to destroy any dust which may have entered along with the bullet while at the same time no fresh septic particles can enter.

If the bone be injured a temporary apparatus is applied without disturbing this tampon & the patient is sent to the ambulance or hospital in the rear. There the wound is thoroughly washed out & treated aseptically [throughout much of this paper, Cheyne has crossed out *antiseptically* or *antiseptic* & replaced it with *aseptically* or *aseptic*, as he does here – JC] Should no spray be present its absence may be neutralized by the use of some of the methods described under the head of country practice. If gauze is not to be had oakum answers

Aseptic treatment in war

Reyher's method.

Tampon of salicylic cotton

[Note added in pencil: *Esmarsch's*]

& application of a steady apparatus

Treatment at the hospital.

Mr. Lister's method.

washing out the wound

ligature of vessels.

Extraction of bullets &c.

Dressing. Permanent dressing.

After dressing.

Change of dressings

Strength of oil used.

extremely well as a substitute.

In the British Medical Journal for Sept^r 3^d 1870 Mr. Lister describes a method for the use of army surgeons. He suggests that the wound should as soon as possible be thoroughly washed out with 1-20 carbolic lotion, the surrounding skin being at the same time purified. Any bleeding vessels are secured by catgut, by torsion or by carbolised silk. While the wound is full of lotion extract the bullet, clothes &c. Then cover the wound with 2 or 3 layers of oiled silk smeared on both sides with carbolised oil 1-5. Over this apply layers of lint soaked in the 1-5 oil overlapping the oiled silk for about 3 inches in every direction & about $\frac{1}{4}$ inch in thickness. This is covered with gutta-percha tissue & the whole is fastened on with a bandage soaked in carbolic oil. This is the permanent dressing. Outside this another & larger dressing of oiled lint covered by gutta percha tissue is applied & changed daily. During the first day apply fresh oil to the outer cloth once in 6 or 12 hours. On the following day the outer dressing is changed[,] carbolic lotion first being introduced under the edge, as it is lifted, by means of a syringe (or carbolic oil may be poured in). After the first dressing use the one to 10 oil solution & later 1-20. On the second day oil is only applied once in 12 hours[;]

after that it is applied daily for 5 or 6 days & then once in two days.

Compound fractures

In compound fractures use a wire splint next the deep dressing & apply the fresh superficial dressings outside the wires. The splint need not be removed till union is complete, the oil being merely poured between meshes when the dressing is changed.

Here as in civil practice attempts will be made to save cases of gunshot wounds of bones & joints which would otherwise be amputated or excised. Each case must be carefully considered – the main point being the possibility of purifying the wound of course[,] together with attention to such points as wounds of large nerves, vessels &c.

Development [sic] of the aseptic method.

It will be interesting to trace now the gradual development of this system following Mr. Lister's own descriptions. This will not only be interesting but instructive as showing how aseptic surgery may be carried out in circumstances where spray, gauze &c cannot be obtained.

First case.

The first cases in which the treatment was tried were Compound fractures & the first attempt recorded by Mr. Lister was made in March 1865. This attempt

was unsuccessful, as Mr. Lister subsequently believed, from mismanagement (See numbers of the Lancet for 1867).

Pure acid used.

The next case was a compound fracture of the tibia caused by the wheel of a wagon passing over the leg. The external wound was in this case 1 ½ in. long & ¾ in. broad. A piece of lint dipped in strong liquefied carbolic acid was placed upon the wound. Four days later this lint was removed & the wound dressed with lint soaked in water & carbolic acid. (At this time very impure carbolic acid was used & it was concluded that carbolic acid was insoluble in water). 5 days later, a solution of 1 part of carbolic acid in from 10 to 20 parts of olive oil was used for 4 days & then ordinary water dressing was resorted to.

Aim to form a scab.

The aim in this case was to form a scab, consisting of lint, carbolic acid & blood, - which would protect the deeper parts from putrefaction. In this case this scab came off on the fourth day &, in order to avoid this occurrence, Mr. Lister, in his next cases, applied a piece of lint dipped in pure carbolic acid as before, large enough to overlap the sound skin for ¼ inch all round. This was covered with oiled paper & outside this a piece of lint soaked in pure carbolic acid was placed for the first 4 days. The crust was then left untouched till

In next case attempts to prevent scab falling off.

To prevent acid evaporating

the 11th day & then water dressing was applied.

As to purification of the interior

It now became evident that, the carbolic acid becoming very volatile, it was necessary to apply means to prevent its evaporation. Accordingly in the next cases a layer of sheet lead or of block tin was applied outside & overlapping the crust.

Necessity for purifying the wound recognised

Up to this time there was no attempt made to purify the interior of the wound in the first instance. How was it then that no putrefaction occurred? Probably for the following reasons. It may have been that no septic particles had got into the interior of the wound because the blood flowing constantly out would prevent the entrance of solid particles unless there was much dirt introduced at the time of the accident or much movement of the fragments & consequent introduction of air. Further if any septic particles were present they may not have been able to produce any effect in the presence of healthy living blood clot (This will be discussed hereafter). Lastly the strong carbolic acid, though applied only to the surface, rapidly spreads into the interior even for the depth of one or two inches.

The necessity for purifying the deeper parts of the wound became however soon evident. A case was admitted in which, when the tissues around the wound were pressed, bubbles of air escaped along with the blood.

Here Mr. Lister squeezed out as much of the clotted blood &c as he could & then applied a piece of lint dipped in pure carbolic acid slightly larger than the wound & over this the piece of block tin. This crust was daily painted with carbolic acid, the tin cap being reapplied on each occasion. This treatment was continued for 3 weeks.

More thoroughly done

This purification of the deeper parts was carried out more thoroughly in the next case in which a portion of the ulna was sawn off & here the whole of the interior of the wound was swabbed out with pure carbolic acid. In this case Mr. Lister first became acquainted with “antiseptic suppuration”, suppuration due to the irritation of the antiseptic applied. The evil effects of the pure caustic carbolic acid in causing excoriation of the skin had been already noticed.

Still more thorough

Finding that no harm resulted from the free application of pure carbolic acid to the interior of the wound in the last case, the next which came under notice was more thoroughly treated. The contused mass of skin was well manipulated & squeezed so as to induce the liquid carbolic acid to penetrate into all the interstices of the wound. In order to permit cicatrization the crust was clipped away around the margin & a solution of sulphite

To permit cicatrization

of potash (5grs [grains] to [the] oz.) applied.

In future the method was always adopted of introducing strong carbolic acid into the wounds by means of dressing forceps holding a piece of lint soaked in the undiluted acid. The blood clots were as far as possible removed.

In order to obtain a more substantial crust & one less likely to be detached where there was too little blood a paste was made use of composed of starch moistened with carbolic acid placed outside a piece of calico soaked in pure acid applied next the wound. As a rule however there is enough of blood to form a substantial paste if several layers of calico are used.

A great risk of putrefaction was experienced all along owing to the fact that the pure acid could not be made to overlap the skin surrounding the wound owing to the excoriation caused by it. This risk was especially great in the first 24 hours during which there was a great flow of blood & serum. Hence attempts were made to obtain some sort of dressing containing the acid in a more diluted form & the first fruits of these attempts was [sic] the formation of various pastes of which the chief was long known as carbolic putty. This consisted of a 1 in 5 solution of carbolic acid in boiled linseed oil mixed with common whitening (CaCO_3) to the consistence

To get substantial crust where little bleeding

Risk of putrefaction because the strong acid could not overlap.

Hence various pastes used.

Carbolic putty.

Fixing the paste

*[Note added in ink] Later it was found better to apply this putty between two layers of calico & then the block tin outside all.

Advantages of putty over former dressing.

Disadvantages of putty. Apt to crumble away &c.

Hence plasters tried

of a firm paste or putty. This was then spread on a sheet of block tin forming a layer about $\frac{1}{4}$ inch in thickness. A piece of lint dipped in 1-5 oily solution was retained permanently next the wound so as to prevent its exposure during the changing of the dressings: The whole dressing was firmly fixed down by means of a continuous series of plasters which however were absent at one part – the most dependent portion – so as to allow the escape of discharge which was received on a towel.*

The advantages of this dressing are:- the tin applied outside prevents the escape of the carbolic acid, the acid in the putty is just sufficiently diluted not to excoriate the skin while the paste serves as a reservoir for the acid during the interval of the change of the dressings, the discharge as it flows out beneath the putty takes up only a certain amount of the acid in its course. If necessary the strength of the acid in the putty may be reduced.

Its disadvantages are that it is clumsy & inconvenient to manipulate & it is very apt, when it becomes dry, to crumble away & thus become an uncertain dressing. Attempts were therefore made to improve it & recourse was had to various forms of plasters. The first of these was the lead plaster (British Medical Journal Oct^r 31st 1868)

Lead plaster

This consists of emplastrum plumbi with $\frac{1}{4}$ part of bees wax & with pure carbolic acid in the proportion of $\frac{1}{10}$ of the whole. The emplastrum plumbi & the beeswax are melted & mixed together & allowed to cool till the liquid begins to thicken, the carbolic acid is then added & the whole well stirred till it thickens. Any degree of firmness is obtained by adding litharge.

(The following is a more detailed account.

Take of olive oil 12 pts. by measure

Take of litharge (finely powdered) 12 pts. by weight

Take of Bees wax 3 pts. by weight

Take of cryt. carbolic acid $2\frac{1}{2}$ pts. by weight

Heat half the oil over a slow fire; then add the litharge gradually, stirring constantly till the mass becomes thick or a little stiff. Then add the other half of the oil, stirring the mass as before till it becomes thick. Then add the wax gradually till the liquid again thickens. Remove from the fire & add the acid stirring briskly till thoroughly mixed. Cover up close & set aside & let the litharge settle, then pour off the liquid & spread upon calico)

Method of dressing with lead plaster.

The wound was dressed with layers of lint soaked in carbolic oil & this dressing was covered in all directions with the plaster. This plaster was renewed daily.

To prevent deep dressing being raised

Objections to lead plaster

Lac plaster

To prevent sticking

As with the putty, so this deep dressing was apt to become displaced, & therefore Mr. Lister used lead plaster as the outermost layer of the deep dressing in the hope that it would adhere to the skin & prevent lifting of the edges of the dressing. In order to prevent the outer layer of the plaster from sticking to this inner portion a piece of calico moistened in the watery solution was interposed. But though the plaster does very well for the outside layer it does not do for the permanent dressing for it allows the watery solution from the calico to soak through to the wound beneath. At the same time this deep layer, not having formed a crust, is apt to shift its place & to leave the wound more or less exposed.

Mr. Lister accordingly tried other sorts of plaster & at length in shell lac he seemed to have found all that he wanted. This lac when melted mixes in any proportion with carbolic acid & is more or less fluid or tenacious according to the quantity of acid present. The shell lac parts but slowly with its acid & thus forms a good dressing. It is however very apt to stick & in order to prevent this Mr. Lister interposed a layer of guttapercha between it & the skin. The carbolic acid passes through

Use of gutta percha for this purpose

Objections to it

Solution if gutta percha then employed

Method of preparation of shell lac.

the guttapercha with extreme readiness while the latter prevents the lac from sticking to the deeper parts. This gutta-percha tissue is however apt to crack & then the discharge gets between it & the lac plaster & thus the fluid beneath it gets but little carbolic acid. Hence the same results happen with this cracked guttapercha as if protective comes to the edge of the dressing – a deep layer of the fluid is more or less protected from the action of the acid & putrefaction can spread inwards.

After several experiments he ultimately employed a solution of guttapercha in Bisulphide of carbon brushed over the surface of the lac plaster. The following is the method of preparing the lac plaster

Take of shell lac 3 parts

Take of crystallised carbolic acid 1 part

“Heat the lac with about 1/3 of the carbolic acid over a slow fire & add the remainder of the acid & stir briskly till the ingredients are thoroughly mixed. Strain through muslin & pour into the machine for spreading plaster &, when the liquid has thickened by cooling to a degree sufficient, spread to the thickness of 1/50th of an inch.

Afterwards brush the surface of the plaster with a solution of gutta percha in about 30 parts of bisulphide of carbon. When

the sulphide has all evaporated, the plaster may be piled in suitable lengths in a tin box without adhering, or rolled up & kept in a canister.”

Where adhesiveness is wanted

For the permanent dressing in compound fracture adhesiveness is wanted & this is obtained by rubbing off the guttapercha & brushing liquid carbolic acid over the surface.

Necessity for protecting the healing parts

At this time (1868) the necessity for protecting the healing parts from the direct action of the carbolic acid was beginning to be recognised & Mr. Lister first speaks of the use of thin block tin or sheet lead as a protective.

Watery solutions obtained

At the same time[,] having obtained a purer carbolic acid soluble in water[,] he gives up the application of the pure acid to the interior of the wound in compound fractures & syringes it out with a solution of 1-20 instead.

Method in March 1870

In the British Medical Journal for March 19th 1870 a description is given of the method then used. The wound was in the first instance thoroughly syringed out with 1-20 carbolic lotion. Then oiled silk covered with a layer of dextrin is applied in one or two layers & outside this the lac plaster. If much discharge is expected[,] lint on a towel is placed outside the lac plaster in order to absorb the discharge. Where the dressing is left undisturbed for a week 2 layers of plaster are used. Where a small piece of

lac plaster is applied as a deep dressing & where consequently the guttapercha is rubbed off to allow the plaster to adhere to the skin the guttapercha is left at the part so as to afford a channel for the escape of discharge.

In changing these dressings a solution of carbolic acid 1-20 is thrown over the wound by means of a syringe as the dressing is lifted & then a guard soaked in the solution is applied. In 1869 catgut ligatures were introduced.

The objections to the lac plaster are that the discharge putrefies outside the plaster & irritates the skin – that the lac keeps the surface beneath it moist with what is really a film of watery solution of carbolic acid & this again makes its way under the protective & irritates the wound. Then lac plaster, from keeping the surface moist, interferes with the use of strapping.

In the British Medical Journal for Jan^r. 1871 Mr. Lister first mentions the gauze dressings & also refers to the use of oakum. The spray is also tried. In Aug. 1871 this method has been established, the present protective was completed, & mackintosh was substituted for gutta percha below the outer layer of the gauze.* Here the piece of gauze next the wound was not wet. It was some

Objections to lac plaster.

Gauze introduced 1871

Also spray

*[Note added in ink] The drainage tube is first mentioned in August 1871 in the treatment of wounds though it had been used for a short time in the case of abscesses.

Wetting of deep layer of gauze

Steam spray.

Elastic bandage.

Application in abscesses.

First case.

2 or 3 years later that the necessity of wetting the deep layer was recognised & since that time the results have been much more constant. With the introduction of the steam spray, of the elastic bandage & of the wet gauze there has been a marked improvement in results & an increasing rarity of putrefaction.

Very shortly after the use of this method in the treatment of compound fracture, it was applied in abscesses.

The first publication on this subject appeared in the Lancet for July 27th 1867. The method of opening the abscess & of changing the dressings are very important with regard to the question of operating & dressing without a spray. A piece of rag dipped in 1-5 carbolic oil is laid on the skin where the incision is to be made, the lower edge of this rag being raised[,] a knife dipped in the oil is at once plunged into the abscess & the rag immediately dropped over the orifice through which the pus is pressed out. A piece of lint soaked in the oily solution is then introduced into the opening in order to stop bleeding & to prevent it from closing. This is done by slipping the strip of lint under the antiseptic rag. With regard to the dressing the putty is here described & used outside a deep dressing of carbolic oiled lint, a layer of calico being interposed between the putty & the

deep dressing to prevent them from sticking together. The putty is changed once in the 24 hours or oftener if necessary. In doing so a rag dipped in the oily solution is placed over the wound or the deep dressing the instant the old putty is removed. If a plug of lint is in the first instance introduced it is after a time withdrawn by pushing oiled forceps under this piece of oiled rag, seizing hold of the plug & pulling it out – or the oiled rag being pressed thoroughly around the forceps. If a probe is introduced it must be oiled & then slipped in between the folds of the oiled rag. As the various means described under compound fracture were introduced they were applied to abscesses on the principles already described.

First method applied to wounds.

The first example of efficient aseptic [changed from *antiseptic*] treatment in the case of wounds of which I find mention is published in the British Medical Journal for Oct^r. 3rd 1868. The case narrated is one for badly united Potts' fracture.

“On the 11th instant (Ap. 1868) the man being under the influence of chloroform I made a curved incision behind & below the prominent end of the tibia; &, a solution of carbolic acid in 4 parts of olive oil being dropped into the wound during the progress of the operation, I detached the soft parts from the bone sufficiently to enable me to insinuate behind the callus one blade of a pair of cutting pliers smeared

*{Note added in ink] Another method of aseptic surgery by filtering air by Lister & Baxter – use still in [?]

Substitutes for carbolic acid.

[Note added in pencil] Eucalyptus oil, acetate of alumina[?]. See MacCormac[?] 133. Escmarch's War

Salicylic acid dressings.

with the same oil & then having placed pieces of lint, soaked with the oil, around the blades of the pliers so as to prevent the chance of the septic air entering the joint when the bone gave way, divided the callus, & at once covered the wound with the antiseptic lint... The wounds were then dressed with a weak oily solution of carbolic acid & covered with the antiseptic (lead) plaster. Fresh plaster was applied daily.”*

Such are the essential details of aseptic surgery as introduced & practised by Mr. Lister. The disadvantages arising from the irritating & poisonous qualities of carbolic acid have led some to seek other antiseptics as substitutes for carbolic acid. These attempts however have not yet succeeded in finding a substance possessing so many advantages as that acid. The most successful substitute has been salicylic acid which is used on exactly the same principle but not with the same constant antiseptic result.

The use of salicylic acid was first advocated by Prof. Thiersch of Leipzig & the following is a short abstract of his method of using it.

The salicylic acid is nearly related to carbolic acid. Its formula is $C_7H_6O_3$ differing from carbolic acid in containing the atoms of carbonic anhydride (CO_2). (The formula of carbolic acid is C_6H_6O). Salicylic acid is not poisonous but it affects the hands in the same way as carbolic acid. It is absorbed & may be found in the urine of patients whose wounds are dressed with it.

Salicylic lotion

A lotion of salicylic acid is employed. This is a saturated solution of acid in water at the ordinary temperature & its strength is about 1-300.

Salicylic dressings

As dressings there are two materials used – salicylic wool & salicylic jute.

Salicylic wool is cotton wool impregnated with salicylic acid in the proportion of 3 & 10 p.c. by weight.

3 p.c. wool.

The 3 p.c. wool contains 750 grammes of salicylic acid dissolved in 7500 grammes of spirit (83p.gr.) then diluted with 150 litres of water at the temperature of 70° - $80^{\circ}C$.

25 Kilogrammes of pure cotton wool are then saturated with this.

10 p.c. wool

The 10 p.c. wool contains 1 Kilogramme of salicylic acid dissolved in 10000 grammes of spirit (838p.gr.) [sic – should perhaps be 83p.gr? - JC] mixed with 60 litres of water.

10 Kilogrammes of pure cotton wool are soaked in this .

Method of preparing the wools.

*[Note added in pencil] It is important to note that Thiersch in speaking of 3 p.c. & 10 p.c. means wool soaked in solutions of that strength in the manner described. Such wool does not by any means contain that percentage of salicylic acid when prepared.

Salicylic Jute

This dressing is best done in a large wooden vat, in which the layers of cotton wool have plenty of room. It is best to place only small quantities of wool in this at a time (2 or 3 kilos.) in order to get an equal distribution of the acid. Thin layers of cotton wool are introduced into the salicylic solution under light pressure, fresh layers being added only when the former have been thoroughly soaked. When the whole quantity has been introduced the whole mass is turned round so that the undermost layer becomes the uppermost, left for about 10 minutes so as to have equable distribution & then the mass is taken out of the vat in layers. By cooling, the acid crystallises out, & the layers are made up into small parcels not exceeding 2-3 Kilos. After 12 hours this wool is spread out in a pretty warm place to dry. It ought not to be hung up lest it should become unequally distributed.

*The 10 per cent wool is coloured with carmine for the sake of distinction.

This cotton wool does not absorb fluids well & therefore Thiersch now uses Jute. This is the best of various species of corchorus [sic] grown in Bengal & is cheaper than cotton wool & at the same time more absorbent. It is also used of

To fix the crystals add glycerine

As to spray in this treatment
generally carbolic.

For disinfecting hands &c

For instruments carbolic is used.

two strengths viz. 3 & 10 p.c.

In order to prevent the shaking out of the crystals of salicylic acid which cause violent sneezing[,] coughing &c. glycerine is added.

For the 3 p.c. jute 2500 gr. of Jute are put into a solution of

	75 gr. of salicylic acid
in	500 gr. of glycerine
&	4500 gr. water at 7. of 70°-80°C.

In this glycerine jute the acid is more equally distributed than in the cotton. On account of the frequent imperfect changing of the cotton in parts it is necessary to place a layer of 10 p.c. cotton next the wound & then outside this the 3 p.c. material. In the case of the glycerine jute a 4.p.c. material is sufficient for the whole dressing.

As to the spray Thiersch does not care whether it is 1-50 carbolic acid or 1-300 salicylic acid. Carbolic acid is to be preferred because it causes less coughing & sneezing & it does not adhere to the clothes. Salicylic acid is best in some cases as it irritates the wound less than the carbolic.

For disinfecting the hands & skin carbolic acid or salicylic acid may be used but for the instruments carbolic acid must be employed

Sponges
Protective
Mackintosh

because salicylic acid oxidizes the steel.

The sponges are washed in carbolic acid.

No protective is required because the salicylic acid is but little irritating.

Mackintosh is also unnecessary.

In order to enable the dressing to peel off & to let the discharge get away more easily a layer of guttapercha tissue or of oiled silk riddled with holes & covered with a piece of gauze is applied next the wound.

Illustrative case.

This treatment may be illustrated by a case of amputation.

The patient having been chloroformed & Esmarsch's elastic bandage having been applied[,] the part is shaved[,] washed with soap & water, spirit & turpentine oil & then with salicylic or carbolic acid 1-20 scrubbed in with a nail brush for a few minutes (quite unnecessary). The operation is done as usual with the usual precautions. After arresting the hemorrhage, stitch the wound with deep & superficial stitches. Then a drainage tube is introduced into each angle of the wound & the wound is washed out with salicylic acid till the fluid comes out clean (unnecessary). Then 3 finger's [sic] breadth of perforated guttapercha & carbolic gauze is applied. Over this one finger's thickness of strong

salicylic wool & outside this 2 finger's [sic] thickness of weak wool. The whole is then fastened on with a bandage.

First dressing

If the patient complains of pain the dressing is taken down & the wound examined. If not it is left till the 8th or 10th day when it is taken down in order to remove the drainage tube. If any discharge comes through in the first instance fresh wool is put outside the dressing. The second dressing is left till healing is complete.

Irrigation with salicylic acid lotion

Large compound fractures are treated at first by irrigation with salicylic acid. In order to protect the skin from the macerating effect of the irrigation it is from time to time rubbed with palm oil. After all risk of abscess formation (this is not present with carbolic dressings) has passed off & the wound is granulating well one may apply dry salicylic dressing as described before.

Wet salicylic dressings.

Where there is a tendency to inflammation, more especially where there is imperfect drainage with progressive abscess formation wet salicylic dressing may be applied. This is ordinary salicylic dressing which is from time to time soaked with salicylic lotion.

Thymol.

Thymol dressings though for some

time loudly praised are now almost entirely abandoned. The thymol gauze was made in the same way as the carbolic gauze. A thymol solution was made of the strength of 1-1000 by the addition of alcohol & glycerine. This antiseptic is however absolutely useless.

What are the particles which cause putrefaction?

The answer to this question [is] necessary in order to understand other methods of antiseptic treatment.

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

is the nature of the particles which we found to be the causes of fermentative changes & how they act in bringing about these changes.

As is well known there is always present in fermenting fluids some form of minute organism (bacterium &c.) & the view which is now almost universally held by scientific men is that these bodies are the initiators of the chemical change.

As we have seen, fermentation only occurs after the access of particles from the outer world & it is asserted by the supporters of the germ theory of fermentative change that these particles are organisms or their spores & that it is by the growth of these organisms in the fluid that the latter undergoes alteration.

Some however assert that these organisms are only accidental concomitants of the process – in fact a few still maintain that these arise in fermenting fluids from agglomeration of molecules, that in fact they are generated anew as the result of the molecular disturbance, not derived from a parent. It is therefore necessary for us at once to obtain evidence as to the real facts in this matter of abiogenesis.

Organisms always present in fermenting liquids

Fermentation only occurs after access of particles to the liquid from the outer world

Various views as to the relation of these to organisms & fermentation.

Necessary to enquire into facts as to Abiogenesis

Needham's views.

The first views of which we must take notice – as being the first founded on experiment & observation, apart from mere philosophical theories[,] are those of Needham & Buffon published in the middle of the 18th century. Needham's theory was that there is in matter a force charged with the formation & government of the organic world[,] which force he calls “force vegetatrice” [sic]. He imagines that this force, by setting in motion all the particles of matter, excites in some of them a sort of vitality distinct from sensation & produced by the union of two other forces which he terms “force resistente” [sic] & “force expansive”.

Quotations from Needham to show his views.

It may be of interest to quote Needham's own words somewhat in detail. Referring to Spallanzani's criticisms of his work (see *Nouvelles recherches sur les Etres microscopiques* by Spallanzani translated by M. l'Abbé Regley 1769) he says “Il sait très-bien par toute la teneur de mes observations microscopiques, 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 organisé, soit végétal ou animal, qui doit nécessairement préexister et dont la souche primitive sort immédiatement [sic] des mains de Dieu; que cette procession ou prolongation insensible qui doit donner ce germe nouveau, dont la petitesse est indéfinie, pour se conformer à toutes les circonstances possibles, se fait moyennant une espèce [sic] 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'oeil et [sic – should be *est*] au monde visible, un centre où les rayons viennent s'arranger de toutes parts, sans confusion, dans le même ordre qu'ils reçoivent de 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 constants, très-atténuée, 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 cette vitalité n'étant autre chose qu'un esprit très-subtil et très-actif, agissant dans une matière brute ténace et ductile, pour former, selon les forces spécifiques de chaque corps vital, un nouveau système organisé, est très différente, selon mes idées, du principe sensitive, qui ne peut être composé, et encore plus distinguée du principe intellectuel et spirituel, l'âme de l'homme."

Further on 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 sensibles, ou sensibles-intellectuelles."

Again; "L'auteur (Spallanzani) croit que j'ai parlé de la force ordinaire végétale des plantes, par laquelle elles se 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 constituifs, ce qui reste devient une matière gélatineuse et toute filamenteuse qui végète par elle-même en branches vitals, et se partage en corps ronds animée ou pousse au-dehors des globules mouvants.”

“Viola [sic] en peu de mots le vrai tableau, voila[sic] le raisonnement de M. de Buffon et le mien. Il y a certainement un principe de vitalité matérielle, distingué du princip sensitive, seul constituit de la stricte animalité, qui se dispose organiquement, et qui, subordonne 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.”

“Ce principe de vitalité est le seul principe d’économie et d’action dans les vegetaux [sic] et dans une certaine classe de ces êtres, qui paraissant sensitifs sans l’être, servent à lier ensemble le végétal et l. animal sensitif.”

“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.”

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 & 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 period so imperfect as to make it of little or no use for such observations.

The 3rd & only experiments which require mention here 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 & boiled for many minutes organisms developed very readily.

Spallanzani repeated these experiments & he found that though some infusions could be sterilized after boiling for a short time yet it was necessary to keep some 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 & place in a water

Needham's proofs are of 3 kinds

First & second proofs.

3rd or experimental proof.

Spallanzani's results

His method.

bath. The error in this method is probably that the impure fluid[,] when poured into the flask[,] soiled its neck again.

To these experiments Needham objected that Spallanzani had much enfeebled or perhaps destroyed the “force vegetatrice [sic]” of the infusions by keeping them exposed to the action of boiling water for an hour.

This objection was at once met by Spallanzani by showing that in the same infusions, left exposed to the air after this prolonged boiling, organisms rapidly developed & he truly says that if the organisms only come from the fluid & if the power, which this possesses of generating these beings be destroyed by heat, they would remain absent whether the flasks were open or shut. He even went further & heated the vegetables, used for making the infusion, very strongly before infusing them but even here organisms developed.

Needham further said that the small quantity of air remaining in the flasks was completely altered by the exhalations from the fluid & by the heat of the fire & that thus the “force vegetatrice” [sic] could not act. This objection cannot be said to have been in any way answered by Spallanzani. In some cases indeed he succeeded in preventing the appearance of organisms by boiling the fluid for ½ to 2 minutes. In many cases[,] however minute[,] organisms appeared.

Objections to Spallanzani's experiments

1st objection answered

2nd objection answered.

Schulze's experiments furnish an answer to Needham's second objection.

His method.

To prevent this occurrence in all instances it was necessary to prolong the heat for at least $\frac{3}{4}$ of an hour.

As an answer to Needham's last objection the experiments of Schulze (see translation in *Microscopical Journal* 1841) form a most important step in advance. The following was the problem he proposed & the method he adopted to solve it.

The question which he asked himself was whether "the access of atmospheric air, light & 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 [sic] in the infusion; & secondly that the air admitted contained nothing of the kind."

"I filled a glass flask full of distilled water in which I mixed various animal & vegetable substances. I then closed it with a good cork, through which I passed two glass tubes bent at right angles, the whole being airtight. It was next placed in a sand bath & heated until the water boiled violently & 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, & the other with a solution of potash. By means of the heat everything living & all germs in the flask or in the tubes, were destroyed & all access was cut off by the sulphuric acid on the one side & by the potash on the other. I placed this easily moved apparatus before my window, where it was exposed to the action of light & 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 & 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, & the atmospheric air from without entered the flask through the sulphuric acid. 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 & destroyed. From the 28th day of May till the beginning of August I continued uninterruptedly

Results.

the renewal of the air in the flask without being able, by the aid of the microscope, 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 & 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 & Monades, to which were soon added larger Polygastric Infusoria & afterwards Rotatoria.”

Discussion of these results

By these experiments the fear 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 & which was constantly changed was present in the vessel while the second open vessel showed that the power of the liquid to nourish organisms had not been lost by the 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 & whether the bodies falling into the fluid from the atmosphere were organisms or their spores or merely albuminous matters which give rise to organisms was in no way determined.

Schwann's experiment
Objections to these.

And the results of the experiments of Schwann mentioned before leave us in the same position. In his case the burning of the air was simply substituted for Schulze's method of passing it through chemical substances 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, while at the same time it was at that time 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 &c are present in air & are destroyed by heat & he explains putrefaction & other fermentative changes as brought about by these organisms abstracting from the fluids in which they grow materials for their nutrition, leaving the compounds thus broken up to form new combinations.*

*[Note added in ink] The objection that the air is altered by passing through sulphuric acid is not urged by Pouchet who indeed states that no alteration occurs & that organisms can develop [sic] as readily when such air is admitted as in presence of ordinary air.

One most important fact he does mention viz. that

Schroeder & Dusch brought forward further evidence against abiogenesis in boiled fluids.

Needham's objections – the only possible ones – have thus been completely answered.

It only now remains to consider if under any circumstances spontaneous generation occurs. It has been shown that it is very rare.

blood can be received into & preserved in a flask with certain precautions without the developement [sic] in it of any form of life.

Further evidence with regard to boiled substances was brought forward by Schroeder & Dusch & later by Schroeder alone. Their method of experimentation & their results have been already referred to. And here it is sufficient to add that in those cases where putrefaction occurred organisms were present while where no change occurred organisms were absent. By their method boiled meat, meat infusion & malt were preserved after boiling without any appearance of organisms. Difficulties were experienced with milk & yolk of egg but these were finally overcome either by heating to the Temp. of 130°C. or by prolonged heat at 100°C. These experiments are of the greatest importance as in this case there can be no objection founded on any alteration in composition of the air by filtration through cotton wool.

When then we look at Needham's 2 objections, & it must be stated that these are the only two essential objections which have been urged against experiments with boiled fluids[,] & when we compare with them the answers furnished by all observers but more especially by Spallanzani to the first & the most progressively strong replies to the second by Schulze, Schwann & Schroeder & 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 has become necessary for the Heterogenists to change their ground. They must admit that there are present in the air & on surrounding objects particles (not necessarily bacteria or their germs though very probably so) which falling on suitable soil give rise to the developement [sic] of bacteria but at the same time they say that Heterogeny can also occur though possibly more rarely than propogation from a parent.

They attempt to support this in two ways – 1st by denying the accuracy of the former experiments, pointing out that they do not always succeed & that some materials develope [sic] organisms even after prolonged exposure to a high temperature & secondly by pointing to the results of attempts to preserve unboiled fluids & tissues.

In 1859 there appeared the work of one of the most ardent supporters of the view of spontaneous generation viz. Pouchet & it is necessary for us to examine his views & facts somewhat in detail.

Pouchet does not look on these organisms as originating from dead matter through the action of some mysterious force as has been 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

Kind of attempts made to support this

Pouchet's work

His theory

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 development [sic] of Protoorganisms yet he does not think that their origin is due to affinity alone but also to a vital force. 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 [sic] of ova in what he terms the proligerous pellicle – the 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 que seulement elle engendre des ovules spontanés dans le milieu proligère, absolument sans l'empire des mêmes forces qui façonnent des ovules dans le tissu de l'ovaire."

His method of investigation

The problem & method of solution proposed.

As essentials for the production of new forms are a putrescible body, water & air while heat, light & electricity considerably favour the result. Having shown that the first 3 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,

says he “admet que dans nos expériences la génération ne peut s’opérer q’à l’aide de trois facteurs, et que c’est l’un d’eux seul qui récèle les germes des Protoorganismes, il est evident que si l’on prend chaqu’un 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 oeufs ou aux séminules introuvables des êtres divers qu’on voit s’engendrer sous les yeux.”

End of Volume I