

EXPERIMENTS  
ON THE  
TRANSFUSION OF BLOOD  
BY THE  
SYRINGE.

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A FEW months ago I was requested to visit a woman who was sinking under uterine hemorrhagy. The discharge had stopped before my arrival, but her fate was decided, and notwithstanding every exertion of the medical attendants, she died in the course of two hours.

Reflecting afterwards on this melancholy scene, for there were circumstances which gave it a peculiar interest, I could not forbear considering, that the patient might very probably have been saved by transfusion; and that, although there was little

opportunity for operating in the usual manner, the vessels might have been replenished by means of the syringe with facility and promptitude. As it seemed doubtful, however, whether the blood would remain fit for the animal functions after its passage through the instrument, the following experiments were instituted with a view to ascertain the point; and they are now submitted, with all their imperfections, to the consideration of the Society, under the hope, that they may contribute a little to excite the attention of the medical philosopher, and recommend a neglected operation to the experimental investigation which it seems to deserve.

The femoral \* vessels of the dog were laid bare *at the groin*; and a pipe, sufficiently large to fill the artery, was introduced with its extremity toward the heart. On removing the ligature, which had been thrown around the vessel to prevent a premature discharge, the blood rushed out with such impetuosity, that eight ounces escaped in the course of two minutes, and the discharge soon afterwards ceased. From this discharge of blood, the most alarming symptoms arose; distress and gasping, struggling and convulsions, and at length a profound fainting, marked by stoppage of the circulation, by in-

\* Register, Experiment 2.

sensibility, and by a complete relaxation of the abdominal muscles.

In this condition the animal was suffered to lie for a few seconds, when six ounces of blood taken from the artery of another dog, were injected into the femoral vein, in a manner which will be hereafter described. In consequence of this operation, it soon revived; the abdominal muscles became firm, and the respiration regular, sensibility was restored, and the blood again circulated, indeed so briskly, that it pushed away the concretion which had formed in the femoral tube, and rushed out. So sudden and complete was the resuscitation, that the animal seemed rather to awake from sleep, than arise from apparent death.

To give this experiment (which will be found in the annexed register, together with various repetitions,) all its force, it may be proper to observe, that the combination of symptoms just enumerated is mortal, and that whatever the symptoms be, the dog invariably dies, when left to its natural resources, if the blood is suffered, as in this instance, to flow from the femoral tube, until the discharge spontaneously ceases. Transfusion alone can save it.

From facts like these it is evident, that the transmission of blood through the syringe, does not un-

fit it for the animal purposes ; but as this is a principle, which lies at the bottom of the whole operation, it may be proper to confirm it by the following experiments.

The femoral \* vessels of the dog were laid bare as before ; and a pipe was introduced into the artery and vein. Then, by means of the syringe, which will be hereafter described, the blood which was suffered to flow into a cup from the artery, was directly returned into the vein ; and this operation was continued, not for a few seconds only, but for twenty-four minutes. Yet the dog sustained but little injury.

It should be observed here, that if the blood be suffered to flow in a full stream from the femoral artery of a dog below the middle size, about half a pint will be discharged in the course of two minutes ; but as this operation was carried on for twenty-four, and the artery gave off its blood impetuously during the whole time, it follows, that twelve pints of blood must have entered the cup, and been transmitted by the syringe to the veins. The whole weight of the dog, however, did not equal twelve pounds, and hence it is obvious, that the same blood must have passed the syringe repeatedly ; a conclusion which is confirmed by

\* Register, Experiment 6.

the highly arterial characteristics, which the blood had acquired, when the operation terminated. This experiment will be found, together with repetitions, in the appendix; and proves, like the former, perhaps in a still more impressive manner, that blood may be transmitted through the syringe, and this too repeatedly, without becoming unfit for the purposes of life.

From this principle it may be inferred, that the transfusion of human blood by the syringe to the veins of a human subject, may be attended with the most important advantages; but as accidents may occur in attempting the operation, it is necessary to ascertain how far they will affect its success.

Although the blood sustains but little injury when discharged into the cup and promptly transferred to the veins, it seems to suffer in some way or other if the transfusion be delayed.

A dog\* was drained by the femoral artery, and replenished by the vein; but in performing this experiment, the human blood was injected instead of the canine, and it was suffered to be in the cup between fifty and sixty seconds before it was thrown in. The animal expired on the table.

\* Register, Experiment 8.

At first indeed it revived, the blood circulated, the respiration was renewed, and sensibility was restored ; but these flattering symptoms were of short duration, and in the course of a few minutes it died.

In a second\* experiment, conducted in the same manner, but with this difference, that the blood remained in the cup for thirty seconds only instead of sixty, the resuscitation was complete, as the animal, though languid, was able to walk, and became so lively and sensible, that it took a pleasure in being caressed. Yet it died in the course of twelve hours.

From a cursory survey of these and similar experiments, it appears that the blood, by lying in the cup between thirty and sixty seconds, is rendered unfit for the purposes of life. Although, however, on a first view they appear conclusive, they are in reality liable to some strong objections, arising out of a principle which I shall next endeavour to elucidate.

It has been very generally asserted, that the blood of one kind of animals may be substituted with impunity for that of another ; and that the dog, for instance, would suffer but little inconve-

\* Register, Experiment 7.

nience, if it were drained of its own blood and replenished from the sheep. This principle, however, which is now seldom controverted, is rendered extremely doubtful by the following experiments.

Three\* dogs were drained of their own, and supplied with human blood, in the manner already described; only the injection was performed without delay; for the blood was taken up by the syringe while flowing into the cup, and injected into the vein immediately. Yet all these dogs, although they recovered for a time, died, one of them in a few minutes, another in a few hours, and a third several days afterwards. The last, indeed, appeared for a time likely to recover, but it died with a dropsy of the pericardium. It is proper however to add, that another dog, on which a similar operation had been performed by Mr. Goodridge of Barbadoes, a gentleman who was at that time finishing his studies at the united hospitals, eventually recovered. The truth is, the constitution of this animal was so vigorous that it resisted the shock; and yet, for a few hours after the operation, a variety of unfavourable symptoms occurred. This experiment, therefore, is in reality in unison with my own; for it is not contended that the exchange of blood *necessarily destroys*

\* See Register.

life, but merely that it *may sometimes endanger* it.

These experiments acquire additional strength, when associated with others instituted by Dr. Leacock (also of Barbadoes) a few months before; experiments to which I was wholly indebted for my first notions upon this subject. From these it appears, that if a dog is drained of its blood *until apparent death is produced*, it may indeed be revived for a time, and very completely too, by replenishing it from the sheep; but it generally dies in a few days afterwards.

Connected with my own, these experiments of Dr. Leacock possess a peculiar interest; for although they harmonize with them in the general result, they differ materially in their circumstances. It was arterial and not venous blood; the blood of the sheep, and not the human that was substituted; and it deserves *particular notice, that the transfusion was not performed by the syringe, a method of operating with which he was unacquainted, but simply by the tube.*

In considering what has just been advanced, two reflections occur to the mind: first, that transfusion by the syringe powerfully recommends itself, as it enables the operator to inject human blood into human veins; and secondly, that it invalidates the experiments already related, which seemed



to prove, that the delay of the blood in the cup renders it unfit for the animal purposes. These were performed with the human blood ; and it is obviously difficult to determine, whether death must be attributed to the delay in the cup, or to the substitution of the human blood for canine. Nor in operating on the dog can this objection be avoided ; for its own blood coagulates so rapidly, that it cannot be employed. The subject deserves further investigation.

In transfusing human blood by means of the syringe, it is obviously the venous and not the arterial blood that must be injected ; for although it would be easy to induce an attendant to submit to the common operation of bleeding, there are few perhaps but would object to the opening of an artery, even the temporal itself. It is of importance, therefore, to remark, that the venous blood seems to revive an animal, as well as the arterial.

A dog\* was drained of its blood by the femoral artery till apparent death was produced ; a fresh supply was then injected in the usual manner by the vein. In performing this experiment, however, venous blood was substituted for the arterial ; yet the animal recovered, nearly in the same manner as if arterial blood had been transfused. This

\* Register, Experiment 12.

experiment was the more decisive, as the dog was suffered to lie for a few seconds in a state of apparent death before transfusion was attempted.

In transfusing blood by the syringe, there is a risk lest air should be introduced. To ascertain whether this accident would occasion death, five\* drams of atmospherical air were injected into the femoral vein of a healthy dog, which was scarcely larger in the body than a full sized cat, in quantities of a dram at a time : but the animal suffered very little injury. It is true, indeed, that deep sighing recurred during the operation, that the pulse became very irregular, and the muscular system tremulous ; but these symptoms are produced independently of experiment, from the mere alarm occasioned by tying the animal to the table. The general health, however, certainly suffered. There was restlessness, vomiting, and a continuance of the muscular tremor ; and this, it may be remarked, together with the small size of the animal, rendered it difficult to observe the pulse. On the other hand, however, the restlessness continued for a few hours only, and the vomiting occurred but once ; the appetite was little impaired ; the animal recovered in three days ; and during the whole of this period, no symptom of immediate danger occurred. Yet compared with the small

\* Register, Experiment 13.

size of the animal, the quantity of the injection was large.

In a second\* experiment upon the same dog, about three drams of air from the lungs were blown into the femoral vein, without even producing much *temporary inconvenience*; so that it seems indisputable, that small quantities of air may enter the vessels without destroying life.

Nor is this principle, which is confirmed by similar experiments of Dr. Haighton and others, materially invalidated by those which have been made upon the horse. For although it be granted that this animal may be killed by blowing air into the veins; this solitary fact can bear with little weight upon the present question, unless the quantity of the air, and the manner of its introduction be also ascertained.

There is little risk in transfusing the human blood by the syringe, lest the operation should be interrupted by concretion; for its coagulation is slow.

Three drams of blood drawn from the femoral artery of a dog, began to concrete in about ten

\* Register, Experiment 14.

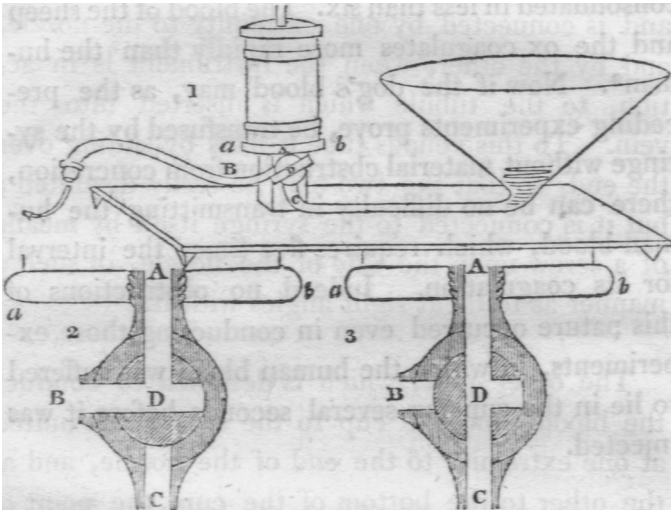
† Register, Experiment 15.

seconds, and had become completely solid in eighty. But an ounce of blood taken from the arm of a girl of an epileptic disposition, but in other respects healthy, did not begin to coagulate distinctly under a minute, and was not completely consolidated in less than six. The blood of the sheep and the ox coagulates more rapidly than the human\*. Now if the dog's blood may, as the preceding experiments prove, be transfused by the syringe without material obstruction from concretion, there can be no difficulty in transmitting the human blood, which requires five times the interval for its coagulation. Indeed no obstructions of this nature occurred even in conducting those experiments, in which the human blood was suffered to lie in the cup for several seconds before it was injected.

It may be proper to remark, that in executing these experiments, both water and weak wine were injected with impunity, and the instrument was not warmed.

\* See Register.

The apparatus used in these experiments, and which it may now be proper to describe, consists of four different parts: the syringe, the cup, the tubes, and the frame.



(Fig. 1.) Exhibits the syringe, &c.

(Fig. 2. 3.) The structure of the double-way cock.

A a b the head of the syringe.

A D B (Fig. 2.) the channel by which the blood is expelled: while A D C is closed.

A D C (Fig. 3.) the channel by which the blood enters: while A D B is closed.

The change is effected by giving the plug D a quarter-turn.

The syringe is constructed in the usual manner; the cup, which is designed to collect the blood, is funnel-shaped; but the tubular part is a little more complicated. It consists of two pipes, with a double-way cock. Of these pipes, one is intended to discharge the contents of the syringe; and is connected by one extremity to the nozzle, and by the other, when the instrument is in action, to the tubule which is inserted into the vein. To this venous tube it fixes by sliding over the end, so that the two may be easily disunited; but it is connected to the syringe itself by means of a screw upon the side of the nozzle, in such a manner as to lie at right angles with it.

The other pipe, which is designed to conduct the blood from the cup to the syringe, is united at one extremity to the end of the nozzle, and at the other to the bottom of the cup, the point of which opens into it. Of course this pipe is formed with a rectangular curve at either end, so as to give an upright position to the cup.

The two-way cock, which completes the instrument, forms a part of the nozzle; and making a quarter turn, throws open the tube which discharges, and closes that which admits the blood, or the contrary, according to the position in which it is placed.

The whole apparatus is mounted perpendicularly

on an upright post ; and the floor on which this rests is poised with lead, in order that the operation may not be embarrassed by the instability of the instrument. The joints are air-tight.

The syringe, which was made by Laundry, of St. Thomas's Street, Southwark, is of brass. Its capacity, which, however, admits of regulation by means of a check on the piston, is eleven drams ; small, in order that the blood may not be thrown into the vessels too rapidly, nor detained too long ; and of a determinate size, in order that the operator may measure the quantity of the blood which he injects.

In constructing this instrument, the tube which discharges should be made of very pliant leather ; and that which admits the blood, may be formed of the flexible metal used for catheters : the first, to prevent the tubule from *wriggling* in the vein during the injection, if the apparatus should move or the animal be restless ; and the last, in order that the situation of the cup may admit of more ready adjustment. For the same reason, the upright post, to which the syringe is to be fixed, although it should not move too easily, may be made to turn round.

Various valvular contrivances might be suggested, to command the orifices of the tubes where they unite with the syringe, and give the proper

course to the fluids it propels. The two-way cock, however, although it is liable to objections, possesses advantages over every other apparatus of this nature, as it is less liable to be clogged with blood or otherwise deranged, and as it may very easily be made air-tight.

The manner of using this instrument, should it be thought proper to operate with it upon the human vessels, may be easily understood. For this purpose, a vein should be opened in the arm or hand of the patient, and a pipe introduced; then, by the common operation of bleeding, blood should be drawn into the cup of the syringe from the arm of an attendant, and injected without hurry or delay.

In performing this injection, the piston should be played with one hand, while the cock is managed with the other; in such a manner as to allow the blood to enter and escape by the respective tubes.

Before the injection commences we must expel the air from the tubes, and ascertain that the apparatus is tight. The air is most conveniently expelled by filling the tubes with water, as the small quantity used for this purpose will produce no inconvenience when injected into the veins.

The tightness of the instrument is essayed, by



putting a few ounces of water into the cup, opening the cock upon the tube of admission, and playing the piston rapidly; for if no bubbling appear, after the air which had lodged in the apparatus has been expelled, it is secure. If the water used in this essay is tepid, it will give a proper temperature to the instrument.

It should be the task of an assistant to take care that the cup never become empty, as air would be drawn in; and this is an accident which the operator himself may prevent, by regulating the injection according to the supply.

On the other hand, however, the blood should never be suffered to accumulate in the cup in too large a quantity. Should it indeed be hereafter ascertained, that the human blood may lie out of the vessels for several seconds, or till it begins to coagulate, without becoming unfit for the animal purposes, it would then perhaps be better, if this instrument were used at all, to draw half a pint of blood into the cup at once, or at least to keep it pretty full; but until this principle is confirmed by *numerous, pointed, and cautious* experiments, such a method of operation would be unjustifiable.

It may be objected to transfusion in every shape, that the tube may excite inflammation of the vein. In weighing this and similar objections, however, it should not be forgotten, that in the present state

of our knowledge, at least, the operation would be justifiable in the most desperate cases only, when it seemed the only mean of saving the life of the patient. There is much good sense in the familiar maxim of Celsus, and in the present case it is peculiarly applicable; for surely it is better to incur the uncertain risk of venous inflammation, than to leave the patient to his fate. Besides, it is not necessary to tie the pipe in the vein; it may be easily secured by the pressure of the finger, or the blood might be injected by an artery.

Although I have described the manner of using this instrument, it is by no means my design particularly to recommend it. Many, perhaps, will think that the common syringe, a little altered in its construction, would perform the operation equally well; and I know that it was successfully employed by Mr. Goodridge in the experiments to which I have already alluded. Indeed, should it clearly appear from future observation, that the entrance of a few bubbles of air into the human veins, or the delay of the blood for a few seconds in the cup or the syringe, does not endanger success; perhaps no reasonable objection could be urged against this instrument, and it strongly recommends itself by its portability and simple structure.

In pointing to some of the advantages which

belong to transfusion by the syringe, I shall not enter into details. I forbear therefore to enlarge on the facility of the operation, or its uses in physiological research; and shall content myself with touching upon three advantages, which appear the most important.

This operation may be performed with *promptitude*; for the human blood is always at hand, and the instrument may be easily provided, as the danger of uterine hæmorrhagies, at least, may frequently be foreseen. Promptitude of operating is no inconsiderable advantage, for the apparent death of hæmorrhagy soon becomes irremediable.

If a dog, drained of its blood, be suffered to lie in a state of asphyxia for a few minutes *only after respiration has ceased*, transfusion itself, aided by the hot bath and artificial respiration, will not revive it. This at least is the general result of the *few* experiments which I have hitherto made; and it proves how speedily the apparent death of hæmorrhagy is converted into the real.

Another advantage which arises out of this method of operating, is the abundance in which the blood may be transfused. A dog below the middle size, (and this variety, perhaps, is the most frequently found about our houses,) generally dies after it has given off from eight to twelve ounces

of blood ; but much larger quantities of *human* blood might be easily obtained from the attendants.

It must be confessed, however, that it is not necessary in cases of hæmorrhagy to throw into the vessels as much blood as they have lost ; a very small supply, although it will not restore the energies of the animal, will preserve its life. This truth, which is in some measure established by the result of the first experiment, is so generally admitted, that it is unnecessary to enlarge upon it ; yet I cannot forbear adding, that it seems to deserve a more minute investigation than it has hitherto received.

But of all the advantages derived from transfusion by the syringe, by far the most important is the opportunity it offers of throwing human blood into human veins. There seems reason for surmising, from facts already related, that the blood of one class of animals cannot be substituted, in large quantities, for that of another with impunity ; and hence it becomes of the utmost importance, that we should be able to supply the human vessels with the human blood. Every other method of transfusion with which I am acquainted, is exposed to this grand objection, that it transfuses the blood of the brute—a defect, from which the operation by the syringe is *exclusively* exempt.

## REGISTER OF EXPERIMENTS

*On the transfusion of blood from the arteries of one dog to the veins of another by means of the syringe.*

I. *History.*—A tube of the full size of the vessel was inserted into the femoral artery; and about ten ounces of blood were discharged in the course of two minutes. No more could be got away.

After the dog had been suffered to lie in a state of apparent death for a few seconds, two ounces of arterial blood taken from another were thrown by the syringe into the femoral vein, through a pipe introduced for this purpose with its extremity toward the heart.

*Symptoms.*—The first symptoms produced by the bleeding were distress, struggling, and laborious respiration; and these were soon followed by gasping, extreme relaxation of the abdominal muscles, and apparent death.

The distress is indicated by a peculiar sort of cry.

A few seconds after injection the animal revived; the abdominal muscles became firm, the respiration regular, and the circulation was renewed with such force, that the blood pushed a coagulum from the arterial tube and gushed out.

*Observations.*—As the dog was small, the quantity of blood drawn away may be regarded as considerable; and it should be observed, that the symptoms enumerated above are, as repeated experiments have proved, invariably followed by death, unless transfusion is performed.

This experiment not only proves, that transmission through the syringe does not unfit the blood for the purposes of life; but shews further, that to obviate the fatality of hæmorrhagy, it is not necessary to inject as much blood as has been lost.

II. *History.*—The blood was suffered in this, as in the preceding experiment, to flow as long as it would from the tube inserted into the femoral artery; and about eight ounces were discharged.

Six ounces were then injected as before, and the dog recovered.

*Symptoms.*—By this bleeding apparent death was produced, together with a whole assemblage of

precursory symptoms, enumerated in the preceding experiment.

*Observations.*—This experiment, performed on the same dog as the preceding, is little more than a repetition of it; but a larger quantity of blood was injected.

III. *History.*—In this experiment the blood was drawn off in the same manner as in the preceding, the following differences excepted. It was drawn from the carotid, and not the femoral artery. It was not drawn at once, but at three different times, a few seconds intervening. The dog was small, scarcely larger in the body than a male cat, so that no more than five ounces of blood could be got away.

After the apparent death had continued for a few moments, the blood of another dog was injected; not, however, till it had lain previously for a few seconds in the cup.

*Symptoms.*—Apparent death was produced, and preceded by the usual symptoms.

In a very few moments after the injection the dog recovered, and so completely, that he leapt from the table as soon as he was unbound. The pulse, indeed, for a little time after the

operation was intermittent and unequal, but these symptoms are frequently produced by merely tying the animal to the frame.

*Observations.*—The lively health of this dog immediately after the operation, was strikingly contrasted with the languor of another, which was supplied in the same manner with the *human* blood instead of the *canine*.

It is obvious from these experiments, that blood is not rendered unfit for the animal purposes by passing through the syringe.



*Transfusion by the syringe from the arteries to the veins of the same animal.*

IV. *History.*—In this experiment, a tube was inserted into the carotid artery and the external jugular vein; and the extremities of both were directed towards the heart. The syringe was then adapted; and the blood, which was suffered to flow into the cup from the artery in a full stream, was directly returned into the vein, in quantities of three or four drams at once. In this manner, about six ounces were transfused, after which the operation was suspended for a few minutes. After this delay, six ounces more blood were, passed in



the same manner through the syringe; only the blood was injected with less impetuosity, in quantities not exceeding three drams at a time. After another pause, four ounces more were transfused; so that the aggregate quantity of the blood which passed through the syringe in this experiment was a pint. No air was suffered to enter into the vessels.

*Symptoms.*—The pulse occasionally intermitted in the first stage of transfusion, but there was no obvious change of temperature.

During the second and third stages, the temperature remained unaltered, and the heart seemed to beat naturally, without labour or intermission.

The dog was rather languid for a few hours after the operation, but recovered without the occurrence of any material symptom.

*Observations.*—It deserves remark, that in this experiment one pint of blood was passed through the syringe without serious inconvenience, although the loss of half a pint would have destroyed a dog of the same size.

The irregularity of the action of the heart arose, perhaps, in part from the injury the blood sustained in passing the syringe; but principally, as

I suspect, from alarm, and from the manner in which the blood was thrown in; for as this was one of the first essays, the operation was not conducted, at the commencement especially, without a little hurry. It should be observed too, that in the first stage, three or four drachms, at least, were injected at once; and as these were thrown into the jugular vein, they must have passed directly into the right auricle—a cavity, perhaps, scarcely large enough to receive them without inconvenience. Accordingly, toward the close of the experiment, when the blood was injected more equably, and in smaller quantities at once, the action of the heart became more regular.

V. *History*.—This second experiment was executed in the same manner as the former, a few differences excepted: The blood was injected at four different times, instead of three; the injections were continued a greater length of time, and the last was pushed so far, that the blood which issued from the carotid artery, acquired the florid arterial colour in a *very high* degree.

Owing to the imperfection of the apparatus, about a dram of air got into the vein.

*Symptoms*.—The pulse intermitted, in consequence of agitation, before the transfusion began; but during the operation these intermissions be-

came more frequent, occurring every five or six beats, so that the blood sometimes flowed impetuously, at others sluggishly, from the carotid artery. The respiration, however, on the whole, continued natural; and the temperature of the animal underwent no obvious change. Toward the close of the experiment, the intermissions became less frequent, and in a few minutes after ceased altogether.

The entrance of the air did not occasion any unusual symptoms.

*Observations.*—The most remarkable symptom occurring in this experiment, which was pushed to a much greater extent than the preceding, was the intermission of the pulse. This must certainly be attributed in part to alarm, for it was observed before the operation commenced; but it seems also to have arisen partly from the unequal and impetuous stream, in which the blood was thrown into the heart. It is obvious, that it cannot be ascribed to the arterial nature of the blood which was injected into the veins, or the changes it suffered in passing the syringe; for although the arterial characters of the blood were heightened as the experiment proceeded, and some of it at least had passed the instrument more than once; these irregularities, instead of increasing, became less and less frequent.

VI. *History.*—This experiment in the main resembled the preceding, but it was performed on the femoral vessels instead of the cervical, and the blood was injected at three different times.

The first transfusion was continued eight minutes, during which the blood was suffered to flow in a full stream from the femoral artery, and acquired the arterial characteristics in a high degree: the second was performed half an hour after the former, and continued for the same length of time: the third was carried on for the same period, after a pause of half an hour, and a few small concretions formed on this occasion in the cup.

*Symptoms.*—Before the transfusion began the pulse was unequal and intermittent, but became regular and distinct as it proceeded. It beat 150 times in the minute, which in this dog was nearly its natural frequency. The respiration was accelerated during the operation, and the dog occasionally complained a little; but its temperature remained unaltered, and the animal ultimately sustained but little injury.

*Observations.*—The regularity of the pulse during this operation is very remarkable, especially if we consider its great irregularity in the preceding experiments. It must be recollected, however, that the transfusion was performed in this

instance upon the femoral vessels, which are remote from the heart, and not on those of the neck.

Half a pint of blood flowed from the femoral artery of this dog in about two minutes; consequently about twelve pints must have been discharged in this experiment, and transmitted through the syringe, in twenty-four. The dog itself, however, weighed less than twelve pounds; and hence it is obvious, that the blood in the large arteries must have issued repeatedly, and repeatedly passed the syringe, which accounts for its heightened arterial character.

The formation of concretions deserves notice, as it proves that the blood in this animal remains fit for its peculiar functions, although certain parts have begun to coagulate.

From these experiments it appears, that the blood remains fit for the vital purposes, although it have *repeatedly* passed the syringe. They confirm the former.

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*Experiments in which the blood was exposed for a short time in the cup.*

VII. *History.*—In this experiment pipes were introduced into the femoral vessels, and about ten

ounces of blood were drawn from the artery, but no more could be got away. Immediately afterwards, about ten ounces of human blood were injected by the vein. This blood was taken from the arm, and about two ounces were suffered to accumulate in the cup, and to lie there for thirty seconds before they were injected. No air got into the vessels.

*Symptoms.*—Apparent death was produced by the bleeding, and the animal revived as usual in consequence of the injection: the pulse beat 120 times in the minute, and did not intermit; the respiration became regular, and the abdominal muscles firm. The extremities and ears felt rather cool; but this symptom is produced occasionally by merely tying the dog to the frame. After the operation, the animal walked, took food, and appeared pleased with caresses; but it died within twelve hours afterwards.

*Observations.*—The dog on which this experiment was performed was aged, but healthy.

VIII. *History.*—This experiment was conducted like the former, but the dog was small, and only four ounces of blood could be drawn away, when a complete asphyxia was produced. The same quantity of human blood was injected, after it had lain in the cup for sixty instead of thirty seconds.

*Symptoms.*—The dog revived for a time, respiration and circulation were renewed, but the recovery was temporary, and it died on the table.

*Observations.*—The dog which was made the subject of this experiment was perfectly healthy, and though small, full-grown. The small quantity of blood drawn away, not exceeding four ounces, renders the death the more remarkable.

These experiments prove, apparently, that the blood is unfitted for its functions by lying between thirty and sixty seconds in the cup of the syringe; but they are invalidated by those which follow.



*Experiments in which the dog was drained of its own, and supplied with human blood.*

IX. *History.*—More than seven ounces of blood were in this experiment drawn from the femoral artery, and six ounces of human blood were injected in their stead. This was received in the cup of the syringe as it flowed from the arm, and thrown directly but tranquilly into the vein.

*Symptoms.*—In consequence of the bleeding, the usual symptoms were produced, and terminated in profound fainting; but the dog revived after the injection. Sensibility was restored, to-

gether with tension of the abdominal muscles, respiration, and a circulation so active, that the blood gushed from the arterial tube. These symptoms, however, continued a few seconds only, when the action of the heart became very irregular, and the dog gasped, gaped convulsively, made ineffectual attempts to vomit, and died.

*Observations.*—This dog was rather large, very lively, and did not undergo much fatigue during the operation. It will be observed too, that the quantity of blood drawn away was not very large, considering the size of the animal, and that a temporary revival was produced; circumstances which make death the more remarkable. Preceding experiments put it, I think, beyond a doubt, that if canine blood had been transfused instead of human, the animal would have recovered.

*X. History.*—This experiment resembled the former, some slight differences excepted. Eight ounces of blood were drawn away from the femoral artery, and six of human blood were injected in their stead. The blood was thrown in without hurry, as fast as it flowed from the arm, in quantities of half an ounce, without being permitted to lie in the cup; but in consequence of the hasty and careless manner in which the apparatus had been put together, a few bub-



bles of air got into the veins. See Experiment V.

*Symptoms.*—Apparent death was produced by the bleeding; but as soon as the human blood was thrown in, the animal revived, and the blood, beginning again to circulate, flowed, though feebly, from the femoral artery; in the course of a few minutes, however, the same symptoms occurred as had preceded the death of the former dog: the animal gasped, yawned convulsively, and vomited; and after lying about an hour upon its side in a state apparently approaching to fainting, it expired.

*Observations.*—The general course of this experiment resembles that of the former; and it may be observed, that the small quantities of air which entered the vessels were not sufficient to occasion death. The proof of this assertion is derived from experiments which will be presently related, and from the event of the Vth, in which a similar accident occurred.

XI. *History.*—In this experiment, four ounces of blood were drawn from the femoral artery, and three of human blood were injected by the vein, in quantities of half an ounce at a time.

*Symptoms.*—The bleeding produced the usual

symptoms, but the apparent death was not so complete as in the preceding experiments; it may be observed, however, that the revival after the injection was more perfect, as the animal did not vomit, and was able to walk, though unstably. Two hours after the injection there was thirst, languor, and debility; and the pulse was so small and weak, that it could not be distinctly ascertained whether it intermitted or not. These symptoms, however, gradually subsided, and on the *third* day it appeared to be rapidly recovering, but drooping a second time one or two days afterwards, it died on the *sixth* with a dropsy of the pericardium. An ounce of fluid had accumulated in this membrane, but there were no signs of inflammation, nor was there dropsy of the other cavities.

*Observation.*—This dog was very small, but healthy and lively.

If we may rely on these experiments, the human blood cannot be safely substituted, *in large quantities*, for that of the dog. It is certain that death was not produced accidentally, from the hurry of injection, or from plethora, from suffering the blood to lie in the cup of the syringe, or the dog to continue too long in a state of apparent death before the injection was performed, for all these accidents were carefully obviated.

*Experiments on the Transfusion of the venous, instead of the arterial blood.*

XII. These experiments were conducted in the same manner as those in which arterial blood was injected, but as the blood flowed rather sluggishly from the femoral vein, the injection was slowly performed. The dogs recovered.

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*Experiments on the injection of air into the veins.*

XIII. *History.*—In this experiment five drams of air were injected into the femoral vein of a dog, in quantities of a dram at a time, and at intervals of thirty or forty seconds. The quantity of the air was measured by means of the syringe.

*Symptoms.*—During this operation, slight difficulty of breathing was produced, and the dog sighed deeply; the pulse, too, became unequal and the muscular system tremulous. As soon, however, as the animal was liberated, it leaped from the table, licked its wound, and seemed pleased with caresses. On the following day it was languid and restless, and the muscular tremors continued; the pulse intermitted occasionally, and the dog vomited once. In other respects it ap-

peared tolerably well, took food greedily, and revived completely by the third day.

*Observations.*—The dog which was made the subject of this experiment, was scarcely larger in the body than a full-sized cat, and very delicate. Its size considered, the quantity of the air which was injected is large; yet all the symptoms may be imputed, in part at least, to the alarm which the operation excited. The effects of these agitations seem sometimes to continue for hours, if the impression is strong, especially in dogs which are naturally timid, as this was.

XIV. *History.*—About three drams of air were blown from my own lungs into the femoral vein of the dog; the greater part of it was introduced at once.

*Symptoms.*—The respiration and circulation were not materially affected, and the dog suffered so little, that a day or two afterwards it was led into the country.

*Observations.*—This experiment was made on the same dog as the former, and in the same manner; but the air which was injected had previously passed through the lungs, and three drams were thrown in instead of five. The animal was less alarmed than in the preceding experiment, and

hence, perhaps, in part the mildness of the symptoms.

From the two preceding experiments it seems that air, whether atmospherical or from the lungs, may be injected into the veins of the dog, and this too in considerable quantity, without fatally deranging the functions.

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*Experiments on the time required for the coagulation of canine blood.*

XV. Three drams of blood, taken from the femoral artery of a dog, and collected in the bottom of a conical wine-glass, began to coagulate in about ten seconds; were wholly coagulated in about eighty. In a second experiment the blood began to coagulate in about ten seconds; and was wholly coagulated in sixty.

The blood of the dog, therefore, coagulates more rapidly than the human.

N.B. As these experiments were designed merely to establish the general truth, they were not made with nicety.