‘TRANSFUSION’
NOUVEAU DICTIONNAIRE DE MÉDECINE ET DE CHIRURGIE PRATIQUES

By: P.C. ORÉ

A TRANSLATION BY PHIL LEAROYD

A copy of the ‘Transfusion’ section (pages 79-143) of volume 36 of the ‘New Dictionary of Practical Medicine and Surgery’ published in 1884 in Paris by Baillière & Sons can be viewed or downloaded from the following site:

https://books.google.co.uk/books?id=xCxy9tV5WEsC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

The author Pierre Oré summarises the content of this entry himself in the fourth paragraph by saying “After having traced a brief history of blood transfusion, I will mention the transfusion operations performed on men and women from 1820 to the present day; I will study the indications, contraindications, complications and accidents of transfusion; finally, I will explain the operating manual.”

As such, this entry amounts to a comprehensive, extensive (i.e. 64 pages long) though sometimes disjointed entry compiled for a ‘dictionary’. Due to the length of the text, I have collected together the main headings (presented in capital letters within the text) and what I believe to be the main sub-headings (presented in italics within the text) as a means of summarising the content:

HISTORICAL
- *Blood transfusion between animals of different species*
- 1° *Transfusion to frogs of human blood and the blood of dogs, rabbits, sheep, calves, guinea pigs, pigeons and pikes*.
- 2° *Transfusion to a mammal of the blood of another mammal*.
- *Presentation of my experiences*.
- *History of the transfusion of blood from animals to humans*.
- *Intravenous injection of milk*.

CLINICAL HISTORY OF TRANSFUSION MADE WITH HUMAN BLOOD.
- 1° C*ases of metrorrhagia occurring either before or after childbirth*
- 2° *Hemorrhages occurring following injuries, surgical operations, various tumours and in cases of pyaemia, septicemia, etc.*
- 3° *Cases of anaemia by various causes, chlorosis and leukaemia*.
- 4° *Cancer, pulmonary phthisis, madness*.
- 5° *In cases of diarrhoea, vomiting, severe dysentery, cholera and typhoid fever*
- 6° *In poisoning by carbon monoxide*
- 7° *Various diseases, malarial cachexia, eruptive fevers, smallpox, scarlet fever, diphtheria, nervous affections, uraemia, asphyxia in newborns, scurvy, gangrene, burns, hysteria, epilepsy, etc..*

ACCIDENTS.
- 1° *Entry of air into the veins*.
- *Does the air exert a disastrous action when it is brought into contact with the blood in the vessels?*
- *How does electricity work*?
- 2° *Defibrination of the blood*.
- *Arguments in favour of defibrination*.
- *Arguments against defibrination*.

INDICATIONS
Mental illnesses.
Anaemias
Inanition
CONTRAINDICATIONS.
OF THE VARIOUS METHODS OF TRANSFUSION.
Injections of blood into the cellular tissue.
What blood should be used for transfusion?
ACCIDENTS OF TRANSFUSION.
EFFECTS OF TRANSFUSION.
INSTRUMENTS AND DEVICES. OPERATING MANUAL.
I. *Immediate transfusion apparatus of Roussel* (of Geneva).
Position of the characters for the direct transfusion of blood.
Preparation of the vein to be transfused.
Bleeding by hand.
The current of water.
DIRECT TRANSFUSION OF ANIMAL BLOOD. – *Operating manual*.
Devices for mediate transfusion.
My transfusion devices.
Manner of using the instrument.
Mechanism of the device.

As can be seen from this list of headings taken from the text, there is some duplication of content and inclusion of what could be considered unnecessary content for a dictionary (e.g. details of earlier versions of transfusion devices), which although is interesting from a historical (or author's personal) viewpoint relating to their development, is somewhat confusing to the reader as to which one is actually available or recommended for use.

There are also a number of confusing statements and inconsistencies within the text. For example having presented and discussed the research performed into the effects of transfusing animal or human blood to humans, the author states that human blood should be used, yet he also then presents details of devices for transfusing animal blood. Similarly, having identified the preference to use non-defibrinated blood, he also presents details for mediate transfusion of defibrinated blood. In addition, having identified the dangers of the activation of coagulation by contact of blood with air and metal surfaces, the author then also presents details of mediate transfusion devices that have 'collection vessels' for donor blood that also include metal valves.

From a historical viewpoint however the content is comprehensive and illuminating and includes a short but important comment regarding the 'new' information of the potential for the transmission of 'parasitic germs' with the blood, especially during the defibrination process.

I have produced a translation of the 'Transfusion' entry of the New Dictionary of Practical Medicine and Surgery from the original French into English to enable its content to be appreciated by a wider audience. Whilst I am obviously aware that instantaneous computer generated translation is available, this process however struggles with accurately reading the original text and interpreting specialist terminology, as well as producing a 'colloquial style' not always representative of the original text. In addition, an 'automatic translation' may either purposely or inadvertently alter the wording to 'make it read better' but in doing so there has to be an element of interpretation involving something on the lines of 'I believe that this is what the author is actually trying to say'. I want to avoid that as much as possible and try to present what the author actually wrote and as a result the reader may find that the English text does not 'flow' as well as it could. Although I have taken great care in accurately identifying the original text and producing a true representative translation of the author's original wording I cannot guarantee that this work does not contain 'translational errors' and the reader is recommended to check specific details against the original text.

I have tried to reproduce the original paragraph settings, line spaces within the text and the general layout as accurately as possible and maintained within the translation the words that are originally printed in italics. The spelling of people's names and the dates of events are reproduced as originally printed (though not all are accurate). The text is not directly referenced but the author includes an extensive bibliography at the end of the entry which is presented as a non-alphabetical continuous text. I have separated and listed these in the order that they are presented, though unfortunately many of the references provided are either incomplete and/or inaccurate.

Pierre Cyprien Ore (1828-1889)
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PIERRE CYPRIEN ORÉ – BIOGRAPHICAL INFORMATION

Pierre Cyprien Oré was a French doctor, surgeon and professor of physiology at the Faculty of Medicine in Bordeaux, where he was born on the 15th November 1828. In 1850 he became a student at the medical school and then an intern at Bordeaux hospitals. His first thesis submitted in support of his doctorate in natural sciences, was titled 'Experimental research on blood transfusion'. He became a surgeon at Saint-André hospital, later becoming a professor of medicine at the faculty of Bordeaux. From 1860 he became very interested in blood transfusion research, publishing the first edition of his book 'Études historiques et physiologiques sur la transfusion du sang' [Historical and physiological studies on blood transfusion] in 1868, the second, much revised edition, being published in 1876. He later however experienced a number of practical blood transfusion failures and as a result, ceased this line of research, retiring from his teaching post in 1878. He continued to practice for ten years as a simple doctor. He was a corresponding member of the Savoy Academy of Sciences (1884-1889) and the National Academy of Medicine (1885-1889) as well as a Knight of the Legion of Honour. He published extensively on other medical subjects and was in 1872 the first person to successfully administer intravenous anesthesia (chloral-hydrate) and in 1875 he published the first monograph on intravenous anaesthesia in humans. He is stated to have been an amateur painter and poet as well as a collector, especially of ceramics. He died in Bordeaux on the 5th September 1889.

TRANSFUSION – Transfusion is an operation that consists of passing blood from the vessels of one animal into those of another. Advocated towards the beginning of the second half of the seventeenth century, it was received with real enthusiasm. But, if transfusion had the privilege of having warm supporters, it also had, from its appearance, violent antagonists, and thus suffered the fate reserved for all great things.

Alternately abandoned and resumed, the transfusion of blood had not made a fortune, and the severe judgment pronounced against it in 1668 by the Châtelet of Paris was still in favour in 1863, at the time when I published my first research.

Since that time, thanks to experimental physiology, the transfusion of blood has entered into a more fruitful path. Everywhere in France, England, America, Germany, Italy, Denmark, Sweden, Russia, the most eminent physiologists and clinicians have made it the subject of their studies.

After having traced a brief history of blood transfusion, I will mention the transfusion operations performed on men and women from 1820 to the present day; I will study the indications, contraindications, complications and accidents of transfusion; finally, I will explain the operating manual.

HISTORICAL – It is in the fifteenth century that we find the first vestiges of the operation.

In fact, we read in the life of Jerome Savonarola, by Villari, this fact mentioned by Sismondi: Pope Innocent VII was plunged into such drowsiness that, at times, he seemed dead. Every means of reviving his exhausted life had been put into use, when a Jewish physician proposed to obtain the desired result by transfusion, by means of the blood of a young person, a means which had hitherto been experimented only on animals. So they exchanged the blood of the old and feeble pontiff for that of a young man. They started again three times, and the experiment cost the lives of the three young men: probably *air had entered their veins*; but no effect was obtained; the pope was not saved, he died on 25 April 1492.

This quotation offers a double interest. It demonstrates that from the fifteenth century blood transfusion had been practiced on humans with human blood. It then shows that, at that time, it was assumed that *the entry of air into the veins was capable of causing death*. I do not believe that any treatise on surgery has ever mentioned this fact, which has always been considered to belong to our century.

Libavius gives the description of transfusion in 1615. In 1625 Giovanni Colle, of Padua, mentions it when speaking of foods and medicines capable of prolonging life, as one of the means suitable for obtaining this goal.

Transfusion, glimpsed by the ancients, only began to take its place among the regular surgical operations at the beginning of the second half of the seventeenth century.

The discovery of circulation on the one hand, and the application of the experimental method on the other were to lead to the solution of the problem.

In France, Dom Robert de Gabets, a Benedictine monk, proposed the *communication* of blood in 1655. The device he recommended was very simple; it consisted of two small silver pipes, joined by a small leather purse.

In England, Richard Lower experimented on animals in 1666.

A German, Jean Daniel Major, claimed that he was the inventor of transfusion, although his writings did not appear until 1667.

It is difficult, from the above, to assign to which French, English and German surgeons absolutely belong in this question the most incontestable rights to priority; but what is very certain is that Richard Lower was the first to make known a complete procedure for operating the transfusion. It should be noted that he performed this operation from *artery to vein*.

Further animal experiments were undertaken in England by Edmond King and Thomas Coxe. They have this particularity, which deserves to be noted, *of having been made not from artery to vein, but from vein to vein.*

At the same time as these facts were being accomplished in England and France, Italian newspapers published experiments undertaken on this subject by Cassini and Griffoni in 1667 and 1668.

Tardy seeks to demonstrate by reasoning that this operation must be even more successful on men than on animals; but, to avoid the inconveniences that opening the arteries would often bring, he believes that instead of making the transfusion from artery to vein it would be better to do it from *vein to vein*. Moreover, this author remarks that the blood of a man is not absolutely necessary for this operation, and that that of a calf or another animal can produce the same effects.

From all the foregoing it follows that the transfusion of blood, practiced on animals, has been followed in a constant manner by the happiest effects.

In a letter written to Moreau, Lamy spoke out against the transfusion. He claims that this operation is rather a new means of tormenting the sick than of curing them, because the diseases for which it is said that it can serve as a remedy are precisely those which come either from the excessive heat of the blood or from corruption. As for the use of animal blood in transfusion, here is how he judges it: “The blood of a calf or any animal is composed of several different particles, intended to nourish the different parts of its body”; he asks, “if we pass this blood through the veins of a man, what will become, for example, of the various particles of this blood which nature had intended to produce horn.”

Entiphronus, Tardy, advises the use of human blood, but they indicate that a certain quantity of blood should be withdrawn before transfusion.

Denys transfused an insane person with calf's blood. This man, who had been operated on towards the end of 1667, remained cured until January 1675; he relapsed at this time. The Faculty, without directly interfering in this affair, made several of its members act secretly and published, under the veil of anonymity, pamphlets against Denys, who applied to the courts. Here is what the sentence contained on the particular point that concerns us: “To practice transfusion freely, it will now be necessary to have the approval of some doctors in Paris.”

From 1665 to the year 1815, the transfusion of blood fell almost completely into oblivion.

Richard Lower talked about it in his work on the heart; the following year Manfredi obtained a success.

Schmidt in 1679, in Dantzick, tried transfusion again and injected drugs into the veins.

In Frankfurt-on-the-Oder, surgeons Balthazar Kaufmann and Purmann cured a leper in 1653 by passing the blood of a lamb through his veins.

Nuck, of La Chapelle, try in their memoirs to bring minds back to the study of transfusion.

In 1753 Michael Rosa, dean of the faculty of medicine at Modena, proved, among other things: 1^{o} that the vessels of a living, healthy animal can admit a greater quantity of blood than they contain without being filled; 2^{o} that the blood of one species can be mixed with another species without harming life; 3^{o} that the revival of an animal that has been bled dry and consequently become inanimate can be obtained by the introduction of the arterial blood of an animal of another species.

This opinion of Michel Rosa was later opposed by the German school represented by Bischoff and Dieffenbach.

Russell, at Eye, County Suffolk, resolved to depart from ordinary methods for curing a young boy suffering from hydrophobia. He opened his veins and let flow such a quantity of blood that he fell inanimate. Then, opening another vein, he gradually introduced, by direct transfusion, the blood of two lambs. The patient soon came to himself and recovered his health and strength.

So, Russell is said to have cured a man suffering from rabies, who he had previously rendered bloodless, by transfusing him with the blood of two lambs.

The students who have followed my physiology lessons at the Bordeaux School of Medicine often heard me repeat that we can only hope to cure rabies through transfusion. I was certainly unaware of Russell's observation when I formulated this opinion.

Blundell, in 1815, did a large number of experiments on animals, and especially on dogs, these experiments, by resuscitating in some way the transfusion of blood, were not to be without influence.

The example set by the English surgeon had to be followed; it was in fact so, and many works appeared then. In France, we see Milne Edwards, in 1823, stating this proposition: "*In serious haemorrhages, recourse may be had to blood transfusion*".

Bischoff, taking advantage of the work of Müller, Prévost and Dumas and Dieffenbach on blood, instituted a series of very interesting experiments (1835, 1838). We must come to the thesis of Nicolas (Paris, 1860) to find two new questions, two important points to which no one had yet drawn attention. In the first place, it is the simultaneous use of electricity and transfusion to revive *bloodless* animals, and in the second place *the influence of cold on the delay of coagulation*.

Finally, there are the experiments of Brown-Séquard on the different action of arterial and venous blood on muscular contractility.

Here are the main conclusions of these various works:

1° When an animal has been reduced to a state close to death as a result of a considerable loss of blood, it can be immediately brought back to life by transfusion (Richard Lower, Denys, Blundell, Bischoff);

2° The quantity of blood necessary to produce this result is always much less than that which the animal has lost;

3° Arterial blood and venous blood both possess the faculty of reviving the animal, but their action is different; the first, red blood, gives the tissues the *faculty* of action, the *power*; the second increases the *action* and implements this *power* (Brown-Séquard, *Society of Biology*);

4° The transfusion, to be successful, must be done with blood belonging to animals of the same class, but especially of the same species, because, if Blundell demonstrated, like all the experimenters, that the blood of the dog revives the dog, he also proved that human blood does not have this property, because all animals, except man, who received it in their veins, quickly succumbed;

5° If an animal of one class is injected with blood taken from an animal of another class (mammals and birds), it succumbs almost immediately, presenting phenomena which offer many analogies with those of poisoning. (Bischoff);

6° The experiments of Prévost and Dumas, Dieffenbach and Bischoff, teach: 1° that blood serum injected alone into the vessels cannot revive an animal on the verge of dying from haemorrhage; 2° that, if we *defibrinate* the blood of a bird and inject it into a dog, it does not cause accidents. It was therefore rational to conclude that fibrin was somehow acting as a toxic agent.

The consequence of this last fact is the *necessity of defibrinating the blood in order to carry out the transfusion* (Bischoff, Giovanni Polli, Nicolas, Brown-Séquard);

7° That, if muscular contractility is brought into play by the injection of venous blood into the vessels, while this property seems to have been destroyed for a certain time, it will have to be awakened with even more energy, when this blood arrives in the heart, at the moment when, under the influence of abundant haemorrhage, the contractions of this organ will be notably weakened, but not yet extinguished. Its active and effective role in transfusion cannot, therefore, leave any doubt.

Transfusion has been, in recent years, the subject of research which has contributed not a little to bringing it into practice. I will mention here the experiments of Müller (of Stockholm), J. Worm Müller (of Christiania) [*Transfusion und Plethora*, 1875], Panum (of Copenhagen) [*Archiv für pathol. Anat*., 1874]. These experiments have been made, sometimes between animals of the *same species*, sometimes between animals of *different species*, either with pure blood or with defibrinated blood. To report them is to make known what I call the contemporary period of blood transfusion.

Transfusion experiments between animals of the same species. – Müller (of Stockholm) made remarkable experiments on the transfusion of blood between animals of the same species. Here are its main conclusions:

1° The blood mass is considerably increased in the first hours following the transfusion;

2° The loss of weight is in no way reduced by the transfusion;

3° The increase in the quantity of urine and urea excreted after the transfusion is indisputable.

The transfusion of blood between animals of the same species has not always been done with pure blood. Defibrinated blood was also used.

The ancients would not have consented to strip the blood of its fibrin, because they considered fibrin to be the essentially active part. It was Hunter's *plastic lymph*, the *restorative element* par excellence.

Magendie concluded that defibrination hindered capillary circulation, promoted interstitial haemorrhage, and consequently counteracted the purpose of defibrination. "Thus," he says, "the same substance which solidifies when it is outside the vessels, but which is liquid in their interior, fibrin, gives the blood the marvelous viscosity necessary to pass through the finest capillaries".

For Claude Bernard, fibrin also serves to facilitate the passage of blood through the capillary networks.

The conclusion that follows from this is that fibrin is a principle that is not useless and which must be preserved, if nothing stands in the way of its conservation.

The experiments of Giovanni Polli and Panum demonstrate that fibrin does not appear to play an essential role in the phenomena following transfusion, which are almost identical, whether or not the blood is provided with this principle.

Blood transfusion between animals of different species. – In 1865, Eulenburg and Landois communicated to the Academy of Sciences some interesting researches on the transfusion of blood. After examining the influence of transfusion in sudden anaemia, on animals exhausted by extensive bleedings, they verified the results obtained by Brown-Séquard, which prove that only oxygenated blood free of carbonic acid can be used for transfusion.

The blood used had just been taken from animals of the same species by opening the veins or arteries of their necks; it was also carefully defibrinated using a reel, until it took on a ruddy color, then poured and heated to 30° Réaumur.

They then experimented with the effects of transfusion in acute and produced poisonings: 1° by gases rendering the blood incapable of performing its respiratory functions by substituting itself for the oxygen of the red corpuscles (carbon monoxide); 2° by toxic substances exerting a deleterious effect on the nerve centres, through the intermediary of the blood (opium).

They resorted to *blood substitution*. This procedure consists in the combination of a simple transfusion, but repeated several times, with the most perfect depletion as possible of the poisoned blood.

In experiments made with carbon monoxide, combined transfusion has been shown to be the safest and most effective remedy, even in severe cases where there was asphyxia and absolute paralysis.

In the experiments made with opium it is possible, in the first case to reduce the duration, as well as the severity of the toxic symptoms; it is also possible to save life and preserve the integrity of all functions by practicing combined transfusion fairly promptly.

Eulenburg and Landois deal with the effects of transfusion in absolute inanition. In such cases the transfusion can prolong life and compensate for a certain period of time for the lack of food and the loss of organic substance worn out during this period. Roussel's experiments on animals and his operations on man have also demonstrated this.

Landois has also experimentally studied the influence that the blood of one animal exerts on another species during transfusion.

1° *Transfusion to frogs of human blood and the blood of dogs, rabbits, sheep, calves, guinea pigs, pigeons and pikes*. – The blood injected into the frog's vessels undergoes rapid modifications: in a few minutes the corpuscles begin to dissolve, as may be convinced by examining at very short intervals a drop of blood which is taken from the frog's leg and preserved in Pacini's liquid.

Naturally, the frog's serum is red as a result of the dissolution of haemoglobin from the transfused blood cells. This is subsequently eliminated mainly through urine. After the injection of calf's blood, the frog's urine still contains albumin on the eighth day, whereas, if a frog is injected with blood (defibrinated or not) from a frog of the same species, his urine does not become albuminous.

We can also observe the dissolution of blood globules on the microscope slide; if frog serum and the blood of another animal are mixed together, we notice that the globules, which at first often take a crenulated shape and exhibit intense molecular movement, then become spherical and consequently appear smaller; then they become more and more pale, so that the stroma itself eventually escapes from view. In the circulatory torrent, the stroma agglomerates and can constitute embolisms. It is to this complication that Landois relates the paralysis of the lower extremities and the symptoms of relaxation of the central nervous system that he frequently observed following the injection of mammalian blood into frogs.

The serum from mammalian blood dissolves, for its part, *in vitro*, the globules of the frog, and it is the same in the vessels of this animal, because, if we inject serum from dog blood, its urine is bloody and albuminous for seven days. Injecting human blood serum and sheep blood simply makes the frog's urine albuminous (not bloody).

2° *Transfusion to a mammal of the blood of another mammal*. – The results obtained can be explained by taking into account the following two facts: A. The serum in the blood of a large number of mammals dissolves the blood cells of other mammals. Dog serum stands out especially in this regard. The serum with the weakest dissolving action is rabbit serum.

B. The globules of the different mammals possess a very unequal resistance to the dissolving action of the serum of the blood of another mammal. Thus the globules of the cat and the dog oppose considerable resistance to dissolution. This is greater at low temperatures than at normal blood temperatures.

Landois' researches would have yielded more practical results if they had been carried out on animals of a very similar species and not on animals of a very distant species. Perhaps they will have the advantage of shedding light on the danger of practicing in man an abundant transfusion with the blood of certain animals, and in particular of dogs.

Panum (of Copenhagen) formulated in 1875 his doctrines on the indication and method of transfusion; he first establishes that no direct nutritional effect can be expected from the blood returned to a patient by the transfusion of defibrinated blood. He found that the total quantity of blood, increased by direct transfusion, from the carotid artery of a large dog into the jugular vein of a small dog, *subjected to complete starvation*, is reduced after a few days to the original quantity; at the same time, the relative quantity of globules is increased in a manner almost proportional to the quantity of blood communicated to the animal by the transfusion.

Panum's experiments also demonstrate that a dog subjected to complete starvation loses every day, after the transfusion of defibrinated blood, more than it lost before the operation: consequently, the life of an animal subjected to complete starvation cannot be prolonged by repeated transfusions. Fibrin given by direct transfusion cannot be of any importance as a nutritional agent either. All this leads us to regard fibrin as an accessory product of the formation of cells, and serving for the production of the materials contained in secretions and excretions.

Nor can it be admitted that transfusion has any utility in cases where the blood is altered by toxic materials, constantly produced and reproduced in the body (for example: in pyaemia, diphtheria, erysipelas, uremia, etc.); the blood (which serves mainly for the transport of decomposition products intended for excretion, as well as for the transport of food materials prepared in the intestinal canal, and of oxygen received in the lung and intended for the tissues) does not contain, at a given time, only a minimal quantity of all

transportable materials, the quantity of which accumulated in twenty-four hours only becomes considerable by the incessant production at the points of departure. The purification of the blood which we have wanted to obtain by the evacuation of the injected blood and by the transfusion of a similar quantity of normal blood is therefore entirely illusory, given that the small quantity of harmful material which we have evacuated is reproduced in the blood a few minutes after the operation. So the results have always been bad in such cases.

The only truly rational indication for transfusion is the lack of a sufficient quantity of red blood cells, capable of combining with the oxygen in the atmospheric air, and of bringing this oxygen to the tissues which need it for their functions.

Panum uses *defibrinated* blood for transfusion and demonstrates that the red blood cells in *defibrinated* blood have retained all their physiological properties for the transport of oxygen.

The author demonstrates with Roussel that the transfusion made in recent times, with the blood of sheep and other animals, tried, abandoned and condemned more than two centuries ago, is still a useless and dangerous operation.

It is useless because it can never render the service required for transfusion, since the blood globules of animals cannot persist in the circulation of man, but dissolve more or less rapidly in the plasma. The albuminoid materials of animals cannot, in any case, be more useful in the blood of man than are the albuminoid materials in the blood of man himself. However, these do not return any appreciable service for the nutrition of tissues.

Moreover, this operation is *dangerous* because the plasma of the blood of animals can dissolve a large part of the globules of man, and because the products of the dissolution of the red blood cells of the animal or man are likely to produce not only an excretion of albuminous matter and haemoglobin with the urine, as well as capillary haemorrhages, but also a serious affection of the kidneys capable of causing a more or less complete suppression of the secretion of urea.

Panum energetically rejected attempts to transfuse humans with sheep's blood as had been proposed by Gesellius (of Saint Petersburg) and Hasse, a practitioner from Hanover.

The success obtained by Hasse in using lamb's blood had such an impact that Ponfick, helped by Bamberger, wanted to submit the question to the rigorous control of the experimental method (1874).

Blood transfusion can be dangerous due to a double action:

1° By a mechanical action resulting from the sudden increase in the liquid mass of the blood; but Worm Müller came to the conclusion that the vascular pressure in transfused animals varied little, to the point that the circulatory tree easily accommodated itself to the quantity of blood that was introduced into it. This bleeding can only be justified in cases of carbon monoxide poisoning; 2° by a chemical action, resulting from the very composition of the blood from the mechanical point of view. Ponfick recognizes the harmlessness of the blood of the same individual or of an individual of the same species (*Archiv für pathol. Anat*.).

Worm Müller, like almost all previous authors, gives superiority to defibrinated blood for human transfusion. For the latter, transfusion is indicated in cases of severe hemorrhage, in certain poisonings (by carbon monoxide, for example), in some old anaemias, after chronic blood loss, as a result of chlorosis and leukemia.

Jacowiecki studied the role of blood during transfusion between animals of the same and different species (*Centralblatt für Chirurgie*, 1874).

When blood removed from an animal was replaced by an equal quantity of defibrinated blood taken from the same animal or another of the same species, it was sufficient to maintain the integrity of functions. Never in this case did he observe the exudations in the tissues, as observed by Magendie.

Unlike Gesellius, when he practiced transfusion between animals of different species, he saw that if the quantity injected is too considerable, the blood decomposes. Then the urine, faeces, vomiting, are heavily loaded with it and the animal dies.

The conclusions which follow from the researches of Panum, Landois, Worm Müller, Ponfick, Lesser, Jakowiecki, Roussel, etc., are therefore unfavorable to transfusion between

animals of different species. Hence the advice never to use the blood of lambs, calves, or sheep in humans, and to use only human blood. This harsh judgment is not without appeal; I hope to demonstrate this soon. In France, some experimenters who have attempted transfusion between animals of different species have been more successful. This is how Brown-Séquard was able to bring back to life a bloodless dog by injecting it with pigeon blood; this animal was kept for three months in Claude Bernard's laboratory.

More recently, Frantz Glénard (of Lyon) has obtained interesting results on this point. He was able, on the same dog, forty-five days apart, to perform two transfusions, one with donkey blood the other with ox blood. Both operations were fully successful. Two new experiments followed; in one they had recourse to horse's blood, in the other to the blood of a donkey; these various bloods were administered after seven hours and twenty-four hours of residence in a segment of jugular vein, and everything worked out for the best.

An experimenter who helped to honour the transfusion of blood from animals to man, Gesellius (of Saint Petersburg), 1874, had previously experimented on animals, particularly on dogs. It would result from twenty-two transfusions (twenty times with sheep's blood, twice with calf's blood) that it is always possible, without prior depletion, to transfuse into a dog a quantity of sheep or calf's blood corresponding to one twenty-fourth of weight of that dog's blood, before seeing the outbreak of worrying symptoms.

Four transfusions of sheep's blood having been performed on dogs in the proportion of one twenty-fourth of the weight of their blood, the kidneys were examined after *ten hours* on two dogs, and after *two days* on the other two (Gesellius has adopted Valentin's opinion on the relation which exists between the mass of the blood of an animal and its weight: this ratio would be represented by one-fifth of the weight of the body). Gesellius concludes from this examination:

The kidneys of animals to which blood of a foreign species has been transfused have the same macro and microscopic appearance as the kidneys of animals to which blood of the same species has been transfused.

Six transfusions were performed, within an interval of eighteen hours, for the first three dogs; of two days, for the three others, an interval which extended from the moment of the operation to the moment when they were killed to examine their kidneys. – All their excretions were carefully collected. Or:

No blood was found either in the urine or in the faeces; there was no interstitial haemorrhage in the viscera; the kidneys showed themselves to be in exactly the same condition as those of a vigorous dog, well fed, unharmed by any transfusion, and which was slaughtered at the same time as the others.

These facts had already been observed, by Gesellius' own admission, by Mittler in 1869.

In consequence of these results, Gesellius believes that he can say that transfusion with animal blood is applicable to man.

Two theories emerge from all of the above:

1° The transfusion of blood between animals of different species, but of the same class, is useless and dangerous, and must be absolutely rejected in its applications to man (professor Müller, Panum, Worm Müller, Ponfick, Landois, Lesser, Jacowiecki , Roussel).

2° Transfusion between animals of different species, but of the same class, can, on the contrary, provide very great services; we must prefer it when it comes to man, according to Hasse and Gesellius, who do not hesitate to declare that "transfusion with sheep's blood inaugurates a new era for medicine, that of the dispensation of blood."

Which of these opposing doctrines contains the truth?

For twenty years I have multiplied the experiments with the aim of researching which of the two it is reasonable to rally around.

Presentation of my experiences. – My experiences date back to the year 1860. A first fact presented itself, which it was necessary, first of all, to verify.

Is it possible to bring back to life an animal that has been bled dry by a severe haemorrhage, by introducing into its vessels blood taken from another animal?

The experiments of Denys and Emmeretz, Richard Lower, Blundell, Dieffenbach, Bischoff, Magendie, Nicolas, mentioned above, can leave no doubt on this point.

My many experiments, undertaken over the past twenty years, also allow me to answer in the affirmative. I will mention only one, which offers all the guarantees of authenticity, by the exceptional conditions in which it was executed.

During a trip I made to Paris in 1868, discussing with Gosselin all the difficulties presented by the treatment of cholera, I urged him to try, in order to cure it, the transfusion of blood. I offered him to attend experiments that I was then doing at the Practical School, in Longet's laboratory; I made him witness to the following fact, which Charles Robin, Lucien Corvisart, and Léon Labbé were also able to observe.

Two tall dogs (about 20 kilos) having been tied side by side I uncovered the left crural vein of one and the right crural vein of the other. I removed from the crural artery of the first, two large blood test tubes, the quantity of which can be estimated at about two litres. Soon the movements of the chest stopped. The ear, applied to the precordial region, distinguished a sort of dull murmur which had replaced the beating of the heart; the muscles of the limbs and neck were in a complete state of relaxation. The animal seemed almost dead. Plunging the cannula of Moncocq's apparatus into the vein of the dog, which had not suffered any haemorrhage, I passed ninety grams of his blood to the one whom I had made bloodless. As soon as the liquid began to penetrate, the movements of the chest reappeared; those of the heart became more perceptible. Life seemed to be reborn as if by magic. After a minute and a half, the dog opened its eyes, the muscles of the neck and legs contracted. At the end of the third minute the dog was saved, I quickly untied him, and after tying the vessels he immediately sprang from the board and began to walk about the apartment. One can understand the emotion of all those present, and their astonishment in the presence of an operation which had brought about an instant resurrection in an animal so near to death.

A similar experiment had been made at the Faculty of Medicine in Paris, in June 1863, with the same instrument and the same success, by Longet. I have repeated this experiment very often with the same success, in my physiology classes at the Faculty of Medicine of Bordeaux.

But if this favourable result has been so easily and constantly obtained, it is because I have made the transfusion with an instrument by means of which I have been able to put the animals in *immediate* communication. Not having at that time at my disposal my apparatus with a rubber bulb, I used that of Moncocq, which had just made great progress from the point of view of operative manoeuvres.

I was operating, in fact, on dogs, that is to say, on animals whose blood is so plastic that it coagulates quickly, shortly after it comes out of the vessels, as soon as it has been subjected to contact with the air.

This need to practice *immediate* transfusion when acting on animals will emerge from the experiments I made at that time to verify certain assertions of Blundell and Dieffenbach.

In his transfusions with *non-defibrinated* blood, Blundell had used the injection syringe. The first question he asked himself was: "Does the passage of blood through the syringe make it unfit to revive functions?"

From his two experiments he concluded: "Blood can be transmitted by the syringe, and this repeatedly, without becoming unfit for vital functions" (*Physiological Researches*, 1824).

Encouraged by the example of Blundell and Dieffenbach, I received the blood for transfusion in a slightly heated vessel and pushed the blood fluid out with a syringe; the failure was complete in a large number of experiments, because the blood coagulated too quickly and thus made the operation impossible.

The first modification I made consisted in receiving the blood in a vessel which had not previously been heated, and which was in temperature equilibrium with the surrounding environment.

I was practicing my experiments in the middle of winter, and I could see that the lower the outside temperature, the more the blood clotting was delayed.

Fearing, however, the presence of the small coagulums, I placed in the flared part of the cannula a flattened circular frame of steel, over which was stretched a wire cloth, the network of which, with a very tight mesh, was to retain the small clots and allow only the part of the blood that remained liquid to pass through.

It is therefore with the help of these two means, refrigeration of the blood and application of a wire cloth behind the cannula, that I have been able to practice a large number of transfusions with complete success.

But it is not enough to demonstrate experimentally that cold delays blood clotting; it is important to know:

1° Whether venous blood, thus cooled, can be injected into the veins of an animal without exerting an unfortunate influence on the movements of the heart, without causing syncope;

2° If an animal reduced to a state approaching death by a considerable loss of blood may be recalled to life by means of a transfusion made with this cooled blood.

Experimentation answered in the affirmative and demonstrated that there was no downside to going down this path.

All the experiments concerning this particular point in the history of transfusion have been made with the venous blood of dogs, which, as we know, coagulates with extreme rapidity as soon as it is exposed to contact with the air. Now, if by cooling it has been possible to preserve it liquid for five, six, eight, or ten minutes, it will be all the more so when it is a question of human blood, the coagulation of which, in the open air, does not begin until four or five minutes after it has left the vessels. The transfusion of blood is freed from the most serious objection made to it, "the danger of coagulation."

I now come to a very controversial question, which has been variously judged by experimenters: I refer to the transfusion of blood between animals of the *same class*, but of *different species*. Müller (of Stockholm), Panum (of Copenhagen), Worm Müller (of Christiania), Ponfick, Landois, Lesser, Jacowiecki, Roussel, etc., reject this mode of transfusion as contrary to the principles of physiology.

Numerous experiments allow me to conclude that the blood of an animal of one species can be transfused without inconvenience and with advantage to an animal of another species, both belonging to the same class.

If in transfusions between animals of different species we often see haemorrhages, haematuria, a special alteration of the kidneys, these phenomena are not constant. Far from depending on the nature of the blood, they are the consequence of the rapidity with which too large a quantity of this liquid has been thrown into the vascular system.

If the doses injected are well proportioned to the weight of the animal; if they do not exceed one-twentieth of the total mass of the blood, these phenomena are most often lacking. When they do appear, they have only a very ephemeral duration and never cause any disorder in the body.

It is therefore possible to replace in transfusion experiments the blood of an animal of one species by that of an animal of a different species. The latter will have an action identical to that of the first.

If the animals belong neither to the same species, nor to the same class (mammals and birds), the blood may be transfused with impunity from one to the other, provided that it penetrates into the vessels of the animal which receives it as it is in the vessels of the one which supplies them, that is to say, perfectly liquid.

It is therefore not to a deleterious toxic action of fibrin that we must attribute, with Dieffenbach and Bischoff, the death which sometimes occurs in these cases, but to the rapidity with which the blood coagulates and to the introduction into the vessels of small coagulums which determine all the accidents of embolisms.

One of the causes that delays blood clotting the most is the contact of this fluid with the vascular walls. This delay in coagulation makes it possible to use the blood of animals of different species and thus creates a new route for transfusion which may become fertile. Kept enclosed in a venous segment of the jugular for 3, 4, 21, 25 hours, bovine blood was kept liquid and could be transfused to dogs without exposing them to any danger.

Istomin and Welikij (of St. Petersburg), always preoccupied with the primordial question of blood coagulation, advise the use in a transfusion device of cannulas prepared by fitting into the interior of a glass tube a piece of a vein of a certain length removed immediately from a living animal. The ends of the severed end are folded over on each side of the tube and secured securely with silk thread. Comparative experiments made with these animal cannulas and glass tubes have shown that the blood retains its fluidity in the former, even when its flow is interrupted, while it coagulated in seconds. The integrity of the inner tunic of the vein is necessary to achieve this result; the vital property of the vein to prevent clotting lasts about an hour and a half.

A last consequence, very important for the practice and success of transfusion, follows from all the foregoing: *it is the physiological identity of the blood of animals of the same class, although belonging to different species*.

History of the transfusion of blood from animals to humans. – Are the conclusions I have just formulated concerning transfusion between animals of the same class, but of different species, confirmed by the observations collected on the sick man?

It is especially in the works of the Italian doctors, Manzini, Rodolfo Rodolfi (1875), Carlo Livi (1875), Caselli (1874), Ponza, Albini; in those of Gesellius (of St. Petersburg), Hasse (of Nordhausen), O. Heyfelder and others, that I will find the answer to this question.

But first let us summarize the facts which date back to the second half of the seventeenth century.

However, the results from the facts of transfusions practiced by Denys and Emmeretz (1667), Lower and King, Balthazar Kauffmann, Purmann, Riva and Russell, that of the *fifteen* transfusions, made either with lamb's blood or with the blood of calves or sheep, from the year 1667 to 1792, *ten* successes were observed, two cases in which the transfusion produced nothing, three unknown results, one case of death.

When a medical doctrine is based on both experimentation and the clinic, it can only be accepted, because it offers all the characteristics by means of which truth imposes itself. The physiological identity of the blood of animals of the same class, but of different species, constitutes an undeniable fact: consequently, the transfusion of blood from animals to man is not only a practicable operation, but one which could render real services.

I do not deny that blood exudations, haemorrhages, haematuria, and a peculiar alteration of the kidneys, have been observed, since I have met with them myself in many animals. But what I affirm is that these phenomena depend not on the nature, but on the quantity of the blood injected; they are the result not of physiological intolerance, but of the plethora of blood.

They can be produced or prevented at will. In my many experiments, I have never, in fact, encountered these disorders when the quantity of blood injected has been rigorously proportioned to the weight of the animal. On the contrary, they have never been lacking if the dose has been too high in relation to the blood mass.

It may be objected to me that Worm Müller, Landois, Lesser, have been able to double, even triple the blood mass, without greatly increasing the vascular pressure, without causing accidents. I will reply that these physiologists have obtained these results only by injecting relatively small quantities of blood extremely slowly. This is how one of Landes' experiments lasted 24 days. Such facts may be invoked as new proof of organic tolerance, but they demonstrate nothing more and remain without practical application.

Also, in cases where blood transfusion becomes necessary, where it is well indicated, the surgeon must always take into account the vascular pressure, and ensure that the quantity of blood injected does not exceed certain limits. Now, my experiments have taught me that by estimating the weight of the blood at one-tenth of that of the body, it will be possible without inconvenience and with advantage to transfuse a quantity of this liquid equivalent to one-twentieth of the total mass of the blood, or two-hundredth of the weight of the body.

Thus, by not exceeding, in his transfusions to dogs, made with sheep or calf blood, one-twentieth of the total mass of the blood, Gesellius observed neither haematuria nor alteration of the kidneys. The same was true in the experiments of Frantz Glénard. Finally, and I

insist on this fact already mentioned, did not Brown-Séquard succeed in bringing back to life a bloodless dog by transfusing it with pigeon blood?

Experimentation therefore authorizes me to formulate as a consequence of my researches this proposition: the physiological identity for the transfusion of the blood of animals of the same class, although of different species.

I have collected 154 observations of transfusions made to man with lamb, mutton, and calf blood. Apart from several unfortunate cases, in which death occurred almost immediately (Lasse had used sheep's blood), it has been possible to say what is remarkable in these animal transfusions, especially in those which have been practiced with lamb's blood, is their efficacy in some cases and their relative safety. Italian physicians have rarely mentioned haematuria; it is true, and this is a fact worthy of note, that the doses of blood introduced into the vessels have always been very small, 8, 10, 12, 25, 30, 60 grams. The absence of accidents is probably due to the fact that the minimal dose of foreign blood was tolerated by the body and that its elimination took place slowly enough to be accompanied by only a few of the disturbing phenomena, which are always observed with higher doses. The improvement in these cases was not very noticeable, as was the blood dose.

Intravenous injection of milk. – Gaillard Thomas proposed intravenous injection of milk. Already in 1850, Dr. Hodder of Toronto (Canada) injected milk three times into the veins of patients suffering from Asiatic cholera; he had 2 healings; once he had injected 450 grams in the first experiment and had immediately obtained a great improvement. In 1877 How (of New York) injected 200 grams of goat's milk into the cephalic vein of a tuberculosis patient who seemed to be dying of starvation, being unable to keep anything, either through the stomach or through the rectum; scarcely 60 grams had entered the circulation when the patient complained of dizziness and headache with nystagmus and abolition of vision; the same phenomena recurred after the introduction of the same quantity; however, after the operation the pulse was stronger, the patient felt better. However, he died 4 days later. A second injection of milk was given to a woman who had undergone an ovariotomy, and who was in a desperate state due to uterine haemorrhages.

Brown-Séquard presented to the Biological Society (1875) a dog from which, 2 months earlier, he had subtracted 95 grams of blood which he had replaced by 92 grams of milk. The animal had been well off, and, according to Malassez's researches, after this injection there had been a considerable increase in the white corpuscles of the blood. The milk corpuscles disappear very quickly.

Brinton, after reporting a certain number of observations of intravenous injection of milk, concludes: 1° It is necessary to inject at least six ounces of milk; 2° the results are as marked after the injection of milk as after the transfusion of blood; 3° there is no danger of embolism after these injections; 4° there is generally albuminuria in the days that follow; 5° the stimulating effects are immediate. Hunter always recommends filtering milk before injecting it.

Henrot (of Reims) advocated in 1878, in the sessions of the medical section of the French Association, capillary blood transfusions; his method consists of making repeated injections into the small veins of the limbs of 15 or 20 grams of blood.

In 1879, Ponfick (of Breslau) proposed the *peritoneal transfusion* of blood; German and Italian doctors have published more than 20 observations of this new mode of therapy: observation and clinic have therefore spoken, and the time seems to have come to make a comparative study on venous transfusion and peritoneal transfusion of defibrinated blood.

Peritoneal transfusion now seems to have taken the place of venous transfusion, especially in Germany and Italy. It was especially Italian doctors who carried Ponfick's idea into the clinical field. A few months later, the German author Bizzozero and Golgi published a series of experiments on peritoneal transfusion made on animals; in 1880 Golgi, Raggi, Concato, Turati, Dagna, Mangiagalli, Viotini Silva, Lanza, Testi, Weagri, Giacchi, did it on man. In 1881 Golgi, Raggi, Seppili, Caselli de Giovanni, also used peritoneal transfusion in the clinic. Foa and Pellacani have published experiments worthy of comment. Mossler, Obalinski, Kakgorowski, Greisfwald, are the only German authors who have tried peritoneal

transfusion on man. In Spain, England, America, France, this mode of therapy has never been tried or studied.

Ponfick has not made any experiments tending to justify his method. The absence of haemoglobinuria in his subjects and the disappearance of the blood from the peritoneal cavity, which could prove the absorption of this fluid by the serosa, seemed to him sufficient evidence in favour of peritoneal transfusion.

Bizzozero and Golgi studied the patients' blood before and after the operation with the chromo-cytometer. They also did experiments on animals. They studied the haemoglobin content of rabbits' blood before the operation; after the operation, they repeated the same study for several days in a row. Rabbits that had previously been bled were also subjected to the same observations. In this way Bizzozero and Golgi were able to convince themselves that the blood injected into the peritoneum really unites with the general blood mass; that the haemoglobin in the blood is still increasing for 43 hours after the operation. This increase in haemoglobin is proportional to the amount of blood injected, unless the injection is too strong. It continues for approximately 27 days. The proportions of haemoglobin show slight differences, depending on whether the animals have been bled or not beforehand. In animals the maximum occurs after 45 hours; for several days thereafter there is a gradual decrease until the haemoglobin has reached the normal average. In animals previously subjected to bleeding, the maximum is noticed within 24 hours; the decrease reaches or is always higher than the level of haemoglobin that existed before the operation. The maximum is also reached more or less quickly, depending on the amount of blood injected. The microscope has never revealed to Bizzozero and Golgi any difference in the shape, volume, and aggregation of the globules.

Foâ and Pellacani repeated the experiments of Golgi and Bizzozero and arrived at the same results as them. They noticed that after a second transfusion on the same subject, the increase in haemoglobin was not as strong as the first time. After a certain number of experiments, this increase does not exceed the normal figure. Peritoneal transfusion causes hyperplasia and redness of the bone marrow; it promotes the genesis of white blood cells and brings a certain excitement to the lymphatic glands and Malpighian follicles of the spleen. The absorption of the blood injected into the peritoneum is through the lymphatics of the abdomen, from where it arrives at the spleen.

In animals killed two or three days after peritoneal transfusion, the mesenteric and lumbar lymph nodes are large and have the consistency of congested marrow. On the fourth day, no trace of blood was found in the peritoneum.

Obalinski, who has studied peritoneal transfusion from the point of view of the increase in the number of red blood cells, found that after the operation the number of globules was always higher than that which existed before.

Peritoneal transfusion in humans gives the same results. In the cases of Golgi, Raggi, Caselli, Negri, Giovanni, the amount of haemoglobin followed an ascending march after the injection. After reaching its peak, it always returned to the normal figure.

Foâ and Pellacani made a comparative study on venous transfusion and peritoneal transfusion. They have seen that the congestion of the marrow is less rapid in peritoneal transfusion than in venous transfusion. Peritoneal transfusion has never caused death, vomiting, or any symptoms of peritonitis in animals.

The instruments adapted to peritoneal transfusion are very simple. Ponfick used a glass funnel to which he adapted an elastic rubber tube. This tube carries at its terminal end a metal needle cut into the shape of a clarinet mouthpiece and equipped with a key; Turati used a hydrocele cannula; from Giovanni a very fine three-quarter; Kakzorowski a three-quarter fitted internally with a lancet to incise the abdominal wall; Caselli imagined an external cannula cut into the shape of a clarinet’s mouthpiece at its terminal end and an internal cannula with blunt edges.

The operative act of peritoneal transfusion consists of three stages. In the first, the blood is collected and defibrinated; in the second, the cannula is inserted and joined to the funnel by means of the elastic rubber tube; in the third stage the injection of blood takes place. Silna and Kakzorowski make these three times in the middle of the cloud of carbolic acid.

It is rare to perforate the small intestine, and no such facts have been reported to date. What is more to be feared is peritonitis, and Concato was able to encounter two cases of it which resulted in death.

In several cases, there was bloating and abdominal pain. Peritonitis is a serious danger for peritoneal transfusion.

It is worth adding that peritoneal transfusion gives only 50 per cent success, while venous transfusion achieves a 70 per cent success, so it is a notable difference of 30 per cent. However, when one considers that in such cases the lives of the patients are at stake, I find this difference in statistics so great that I do not need to dwell any longer on peritoneal transfusion.

Roussel's opinion is that the name of transfusion should, according to his definition, be reserved for the operation which causes the blood of one subject to pass into the vessels of another, and that neither the facts resulting from the injections of *water*, *milk* and other liquids into the veins should be charged or credited with transfusion, nor the effects of injecting blood *out of the vessels*, into the cellular tissue, or into the peritoneum.

CLINICAL HISTORY OF TRANSFUSION MADE WITH HUMAN BLOOD. – Transfusion practiced on animals has almost always been successful, whether blood from an animal of the same species or from different species has been used. Many physicians of our time have obtained very fine results by transfusing lamb, sheep, or calf blood into man himself.

But, if *animal* transfusion has been resumed in recent years, it may be said that from 1820 until a period still close to our own, it had been done exclusively with human blood.

Already in 1863 I had presented a statistic containing 79 cases. Since that time new facts have occurred: thus de Bélina, Marmonnier, in his thesis on the transfusion of blood, the first mentions 175, the other 192. Joseph Casse's statistics contain 292 observations. L. Landois, in his work: *Die Transfusion des Blutes* (Leipzig, 1875), reports an even greater number.

Roussel, of Geneva, operated for the first time with complete success in 1865; in Paris in 1867 the observation, the method and the instrument which he called the transfuser were presented to the Academy of Medicine. German surgeons operated in France in 1871. In 1873 the transfuser was appreciated for its value by the Vienna School, then by those of St. Petersburg, Belgium and England. A good number of operations have been performed in Paris. Today he relies on more than 60 direct transfusions, having given him 59 per cent complete success. Of the cases noted by Roussel as unsuccessful, eight subjects survived without transfusion producing results; twenty-seven patients who could not be cured nevertheless obtained a prolonged survival of three to twenty days; not once did death occur that could be attributed directly or indirectly to the transfusion. No blood donor suffered from his generous sacrifice.

This method allows: 1° to directly transfuse complete, live blood, without danger of clot formation or contact with air; 2° to transfuse the patient the full dose required by his condition; 3° to subtract from the blood donor only the precise quantity that the transfused person receives; 4° not to carry out any dangerous manipulation, ligation or hazardous puncture on the veins of the two subjects; 5° to allow a single surgeon to operate very quickly without preparations and without aids. Only the transfusion and water are necessary.

In my book (1876) I have classified the known facts into seven groups:

1° Blood tr. practiced in cases of metrorrhagia occurring either before or after childbirth; 2° Tr. in haemorrhages following wounds, operations, various tumours, and in cases of pyaemia, septicemia, etc.; 3° Blood tr. in cases of anaemia, chlorosis, leukaemia; 4° Blood tr. in cases of pulmonary phthisis, cancer, madness; 5° Blood transfusion in cases of diarrhoea, vomiting, severe dysentery, cholera; 6° Blood tr. in poisonings; 7° Blood transfusion in various affections, such as smallpox, diphtheria, asphyxia of newborns, eclampsia, hysteria, epilepsy, etc.

I. Used 117 times against metrorrhagia serious enough to make one fear death, blood transfusion has given 77 successes and 40 failures: should it be considered as the cause of these 40 failures?

Always used to oppose a fatal, immediate termination, caused by the considerable loss of blood, in 10 of the patients who succumbed, the transfusion however delayed death.

In fact, death arrived: 1° on the seventh day as a result of uterine phlebitis (D^{r} May); 2° on the twenty-first day by metroperitonitis (Prof. Nélaton); 3^{o} on the fifth day after a marked improvement in the patient's condition as a result of partial peritonitis, suppuration of the bladder, uterus, kidneys, and the presence of pus in the external iliac vein (Lever and Bryant); 4° on the seventh day, the uterus being full of pus (Higginson); 5^{o} on the tenth day as a result of septicemia (Savage); 6° on the twelfth day as a result of puerperal fever (Ackmann); 7^{o} eleven days after the transfusion (Carrey); 8^{o} ten days after the transfusion, following anthrax (Turner and Wills).

In these eight cases, after having escaped the dangers of haemorrhage thanks to transfusion, the patients have succumbed to accidents which are completely foreign to them and which unfortunately tend for the most part to become too frequent complications of childbirth. In two other cases, air penetrated the veins (Jewel and Bayle, Rigten).

In more than three-quarters of cases, the transfusion prevented death.

Roussel performed direct transfusion 8 times in puerperal hemorrhage, and obtained 6 cures. 1 patient died of peritonitis 8 days after the transfusion which had saved her from death by hemorrhage, and 1 patient suffering from uremia died after twelve hours.

Used to combat haemorrhages which occur during or after pregnancy, in spite of the seriousness of the loss, the excessive weakness of the patients, the slowness of the operation, transfusion has been practiced many times, when all the conventional means would have been used unnecessarily, and, more often than not, it has saved women condemned to certain death; the nervous and inflammatory accidents with which Cazeaux was concerned are purely imaginary, for phlebitis has been noted once or twice, and to such a slight degree, that it has yielded to the simplest antiphlogistic medication.

From the careful study of the observations that I have collected I conclude that:

Blood transfusion is one of the most powerful and effective means that the surgeon possesses to combat serious and desperate haemorrhages which occur during pregnancy or after childbirth.

II. *Hemorrhages occurring following injuries, surgical operations, various tumours*.

Blood transfusion has been used 50 times against traumatic hemorrhages. It has given 23 successes, 25 failures, 2 improvements. In 2 cases, it opposed a fatal termination made imminent by too much blood loss. Death was then caused by complications that arose following the operations performed. Thus Danyau’s patient succumbed to immediate amputation, to suppuration accompanied by gangrene of the stump. Simon's patient, in whom the transfusion had been initially successful, had a secondary haemorrhage following a phlegmon of the thigh, and pneumonia.

In three others, death occurred twice as a result of the entry of air into the veins (Walton and Simon); once by arrest of the heart, occurring suddenly following a single injection of 420 grams of blood (Roux): the autopsy demonstrated it.

The number of failures is therefore reduced to 19. This is about the proportion we have already found for metrorrhagia.

Finally, in one of Maurice Raynaud's patients, death had occurred when the transfusion began.

Roussel out of 9 cases of traumatic haemorrhage obtained 4 cures. 2 operated on died from recurrence, 1 tetanus was suspended for 6 hours. 2 failures. Out of 8 cases of chronic uterine haemorrhage, stomach, haemoptysis, etc., he had 6 successes, 1 death after 2 months by recurrence, 1 death on the fourth day. Out of 8 cases of prolonged suppuration until the marasmus, he obtained 4 cures, 4 failures.

Eleven cases of transfusion in cases of pyohemia and sepsis were all fatal.

III. *Cases of anaemia by various causes, chlorosis and leukaemia*.

The transfusion of blood, used 62 times to combat anaemia from various causes, has brought recovery about 33 times and 4 improvements; 25 times it has not been able to prevent death.

Out of 9 cases of leukemia, it produced 3 happy endings; 6 patients died.

IV. *Cancer, pulmonary phthisis, madness*. – Transfusion was used 15 times against cancer, and in only 4 cases did it produce a momentary improvement.

In 13 cases of *pulmonary phthisis*, it produced 3 transient improvements.

In 10 cases of *insanity*, it brought only a cure, the transfusion in this case was done with lamb's blood.

V. In seven cases of *typhoid fever*, the transfusion gave 2 successes; in 4 cases of dysentery, 1 success; in 21 cases of cholera, it provided 3 happy results.

VI. Transfusion has mainly given very fortunate results in *poisoning by carbon monoxide*: thus it is that in 15 cases it has brought about recovery 9 times. The same was true in a case of *phosphorus poisoning*.

Used 3 times in *glanders*, *syphilis* and *rabies*, it has given no results. On the occasion of the case of rabies which Dieffenbach was unable to cure by transfusion, I think I must mention two observations in which rabies was treated by intravenous injections of lukewarm water. One of these observations was published by my friend Dr. Lande, in my *Studies on the Transfusion of Blood*; the other is personal to me.

Dr. Lande's patient died after having presented alternatives of calm and agitation. What is remarkable is that her intelligence is perfectly clear and that she dies only after having made her last recommendations to her family, with great calm and good sense.

I received in my department of the Saint-André Hospital, sometime later, a coachman who had been bitten by a rabid dog and who was at the time of my examination in a state of extreme agitation. I prescribed bloodletting and steam baths. By the evening of the third day, the agitation was extreme; all the symptoms previously described had become noticeably worse. The patient was delirious, uttered violent cries; the pulse was at 140. I injected 700 grams of lukewarm water into the median basilica and I set aside an hour and a half to do this. From 400 grams, calm returned; the pulse dropped. At the end of the injection, it was beating 50 times per minute. Calm had returned from that moment. This man was able to make his will, to address his last farewells to his family, to confess; there is a long way from this narrative to the stories of the last cruelly horrible moments of the enraged!

VII. *Various diseases, malarial cachexia, eruptive fevers, smallpox, scarlet fever, diphtheria, nervous affections, uremia, asphyxia in children, scurvy, gangrene, burns*. – Transfusion has been used in the various ailments that we have just enumerated.

We summarize the results obtained as follows:

1° *Malarial cachexia*: 3 cases, 3 successes;
2° *Eruptive fever, smallpox, scarlet fever*: 6 cases, 1 success;
3° *Diphtheria*: 3 cases, 3 failures;
4° *Various conditions of the nervous system*: 4 cases, 3 failures, 1 doubtful result;
5° *Epilepsy*: 3 cases, 3 failures;
6° *Eclampsia*: 1 case, 1 success;
7° *Hysteria*: 6 cases, 2 successes, 2 improvements, 2 failures;
8° *Uremia*: 3 cases, 3 failures;
9° *Asphyxiation of newborn children*: 5 cases, 1 success, 4 failures;
10° *Scurvy*: 4 cases, 4 successes;
11° *Gangrene*: 2 cases, 1 success, 1 improvement;

12° *Burns*: 2 cases, 2 deaths, one by the entry of air into the veins, the other as a result of a generalized burn.

All the facts of which we here give a summary are the subject of a detailed observation in my *Studies on the Transfusion of Blood*.

Roussel has used direct transfusion 29 times in medical cases: fevers, dysentery, chlorosis, anaemia, poisoning, asphyxia, inanition, melancholy, etc.; he obtained 13 cures, 6 cases without result, the patient having survived not cured, and 10 failures with temporary improvements.

ACCIDENTS. – Two accidents, if they occur often, should make one give up transfusion.

I want to talk about 1° the entry of air into the veins; 2° the formation of coagulums which, if launched into the vascular system, would cause serious and fatal disorders.

I. *Entry of air into the veins*. – The facts of Jewel and Bayle, Rigten, Simon, Walton, Hueter, prove that it can take place while the transfusion is being performed.

It is therefore an argument against the use of this method, the importance and gravity of which cannot be concealed, and from which it must be freed by giving the surgeon, who would find himself confronted with this accident during the transfusion, the means to combat it.

It was for this purpose that I undertook, during the year 1862, the numerous experiments which I am going to report. But before I do I must mention the works of Nysten, Magendie, and Amussat, on the same subject, and make known the results they have arrived at.

My research is divided into three parts:

1° The first contains the experiments in which I introduced pure air into the veins of animals (dogs, rabbits, chickens).

2° In the second, I will report those that I made in the same way with nitrogen, oxygen, hydrogen and carbonic acid.

3° Finally, after having explained the mechanism of death by the entry of air, I indicate the means which seemed to me the most effective to combat this dreadful accident.

The instrument I used to introduce this gas into the blood is Mathieu's hydrocele syringe; the rod of the piston being graduated, it was easy for me to always know very exactly the quantity of cubic centimeters that I was making penetrate the vessels. The veins I have chosen are sometimes the external jugular, sometimes the axillary, sometimes the crural.

Nysten concludes from his experiments: "Every time I have injected a great deal of air into the veins of the animals at a single stroke of the piston, I have caused them to perish with the same phenomena. When they were small like some spaniels, 40 to 50 cubic centimeters of air were enough to kill them quickly. When they were strong as mastiffs, of an above-average size, it was necessary to inject 100 to 120 cubic centimeters of air to cause death."

"It is already presumed from the foregoing," continues Nysten, "that the air injected into the venous system of living animals, causes death only *by excessively distending the walls of the right chambers of the heart*, and by preventing them from turning back on themselves to drive out into the lungs the blood they contain."

In support of this theory of the mechanism of death, the same experimenter cites the following experiment: Into a dog weighing 7 kilograms, he injects 80 cubic centimeters of air. A few seconds after the injection, the animal no longer gives any sign of life. Nysten then opens the subclavian vein and draws out a lot of blood by means of pressure on the chest wall. This done, the animal breathes; the pulse becomes sensitive again and the dog does not die. At the end of three days the animal is sacrificed, and it is found that there is no longer any bubble of gas either in the heart or in any part of the vascular system.

It is quite evident that the atmospheric air injected into the venous system of living animals causes them to perish promptly only by causing an enormous distension of the atrium and the pulmonary ventricle, since it is sufficient to put an end to this distension to recall the animals to life. Repeated a large number of times, these experiments have always been successful.

Magendie also researched the introduction of air into the veins and the possibility of injecting this gas into a vein without causing death. After the work of Nysten and Magendie came the research of Amussat, communicated in 1837 to the Academy of Medicine and which was the subject of a report made by Professor Bouillaud, in the name of the commission responsible for assessing it (*Bull. de l'Acad*., t. II).

Two years later, in 1839, Amussat published the whole series of his experiments. In the first series are those relating to the spontaneous introduction of air into the veins.

In the second, he reports all those into which air has been introduced by force, either by insufflation or with a syringe. Finally, it determines the means to prevent, stop or destroy the accident.

Amussat's experiments led him to these conclusions:

The *depletion* of the vessels by the subtraction of a certain quantity of blood has a great influence on the rapidity of the effects of the spontaneous introduction of air into the veins. For it may be established that when this circumstance occurs, death comes all the more quickly if the animal has lost more blood or has been exhausted by pain. Amussat devotes a chapter to exposing the experiments made with using the forced introduction, sometimes abrupt, sometimes slow, of air into the veins.

Like Nysten, he saw that the air forced into the side of the heart through the jugular or axillary veins, either by insufflation or by injection, almost always causes sudden death in animals of different species. He remarks, however, that the slow and prolonged introduction produces the same phenomena as the abrupt introduction, but in a much slower manner, and which finally makes it possible to observe what happens between the moment of the entry of the air and death.

In these experiments, the phenomena observed are very similar to those resulting from spontaneous introduction; there is, however, a very notable difference: it is that after death, which is determined by spontaneous entry, only the right cavities are generally found distended, while after forced introduction air is often found in the left cavities, as well as in the arteries and veins.

Of all Amussat's conclusions, I will quote only the following two:

1° At the immediate opening of the chest of animals that have died suddenly by the spontaneous introduction of air into the veins, the right cavities of the heart are constantly found distended, bloated by the air more or less mixed with blood, while the left cavities are almost always empty, collapsed, and contain little or no air.

2° The cause of death seems to be attributed to the interruption of pulmonary circulation.

I have just said that my research on the introduction of air into the veins had only been undertaken to answer this question:

Does the air exert a disastrous action when it is brought into contact with the blood in the vessels?

After numerous experiments I was led to add a new cause to the causes of death following the entry of air into the veins, reported by Nysten and Amussat.

Instead of making partial injections of air at more or less frequent intervals, I have always pushed into the vessels, at one time, the quantity of air sufficient to bring about death.

Several consequences arise from my experimentation

1° A more or less considerable quantity of air, injected slowly but continuously into the veins of an animal, brings death almost immediately.

2° The quantity of air necessary to produce this result varies according to the animals; it is less for rabbits than for dogs. In small dogs, 30 or 40 centimetres are sufficient; in medium-sized dogs, 60 to 80 cubic centimetres are needed; in dogs of a larger size, Nysten was able to inject up to 100 and even 120 cubic centimetres.

3° The air, on arriving in the heart, causes the distension of the right cavities, at the same time as it renders the wall of the ventricle immobile, without producing the same effect on the atrium and on the left cavities.

But is it really the distension of the right chambers of the heart that causes death, and does the air have only a purely mechanical action in the production of this phenomenon?

To answer this question, it became necessary to make new experiments: it was necessary to decompose the air, and, taking each of the elements of which it is composed, to ascertain whether, introduced separately, one after the other, into the veins in a quantity equal to the quantity of air which causes death, the latter result could be produced with them. In my opinion, this was the only way to judge mechanical action. The results I have obtained are in opposition to this conclusion of Nysten: that nitrogen injected into the venous system has a more harmful action than atmospheric air, since it generally requires much less to cause painful cries, convulsions, and death, and that by putting an end to the distension of the pulmonary heart caused by the presence of this gas, animals cannot be brought back to life; from this it must be inferred that there is a sedative action on the vital force of the heart.

How is it possible to admit that, if nitrogen has this sedative action on the muscular fibre of the heart, the atmospheric air, which contains 50 per cent of it, is totally devoid of it, and that it produces death only by a simple mechanical distension?

Will it be said that it is the presence of oxygen that neutralizes the nitrogen? But the former is 4 or 5 times more soluble than the latter in the blood: there must therefore come a time when the action of the latter will manifest itself alone.

It was necessary to establish a long series of experiments to verify and control this fact; here are the results:

1° All gases, - air, oxygen, nitrogen, - injected into the veins, can produce death if they are injected in too large a quantity.

2° All these gases can be injected with impunity, if the dose is small.

3° Nitrogen and oxygen can be tolerated in higher doses than air without causing death.

4° The theory which attributes this fatal termination to the distension of the right chambers of the heart alone cannot be admitted; the air seems to exert a sedative action on the muscle fibre, which has the consequence of paralyzing it more or less.

The question of the entry of air into the veins has been taken up in recent times by Dr. L. Couty, in a thesis remarkable from every point of view (1875). Couty rejected the theory of the *sedative* action of the heart produced by air, which I had accepted as a consequence of my numerous experimental researches. If he notes the different role that I make nitrogen and air play, he acknowledges that "Mr. Oré's experiments have been confirmed with regard to CO_2, oxygen and all the gases that are more soluble in the blood; for nitrogen only the facts are contradictory."

But whether air has a sedative action or not, is a theoretical point of little importance in the question with which we are concerned. What must be important above all is the rigorous, absolute demonstration of the fact that: "*air can penetrate into the vessels and remain in relatively considerable quantities, without fatally causing death*."

This quantity, compatible with life, being always greater than that which the instruments used are capable of containing; this complication will not be seen to occur during the transfusion by the very fact of these instruments. If it occurred, it was because the vessel chosen for the operation was placed under the influence of thoracic aspiration; it was then caused much more by this aspiration itself than by the transfusion apparatus. Hence, the precept that one should never choose for transfusion either the jugular vein or any other vein on which the expansion of the thorax exerts its action.

I have thought of combating, with the help of electricity, the accidents produced by the introduction of air into the veins: but how to use the electricity? The anatomical position of the heart not permitting me to think of applying it immediately to it, I have decided to act through the intermediary of the nerves which go to this organ.

The heart receives nerves which come from the pneumogastric and the greater sympathetic; it was on the first that I directed the currents.

Everyone knows that the introduction of air into the veins constitutes one of the most formidable accidents of surgery. No matter how skilled the surgeon may be, death occurs before he has completed certain operations performed either in the hollow of the armpit or in the neck. Amussat reported all known cases in which autopsy demonstrated air penetration. Dupuytren, Bouley, Mirault (d'Angers), etc., etc., were unable to save the patients in whom this accident occurred; all the means proposed to combat it have been fruitless, and to give

the surgeon a procedure which, resulting from experiments made on animals, will enable him to operate with safety, is, it cannot be disputed, an extremely useful application of experimental physiology.

Follin, who had been present in Longet's laboratory at the experiments I had instituted for this purpose, expresses himself on this subject as follows: "A strong stimulation with the help of electricity was recommended by Oré. This surgeon has shown us that by employing energetic electric currents in such a way as to provoke great respiratory movements, death can be prevented, although a quantity of air was injected into the veins greater than that which is sufficient to strike down an animal. Electrical excitation of the pneumogastric in the middle part of the neck seemed to be especially indicated in this case; but experience has shown Oré that the same result can be achieved without directly electrifying the trunk of the nerve. One of the conductors is then placed on the sheath of the nerve or in its vicinity, or even in the mouth of the animal, and the other in a wound made in the chest wall. Whatever the theory, the experiment on animals has been favourable to the views of the Bordeaux surgeon, and in such an accident in man we should not neglect the use of this means."

How does electricity work? – It is the play of the chest alone that determines the suction of the air. It is therefore the dilation of the chest during inspiration that determines the entry of air: but this dilation is one of the principal causes of venous circulation, which exerts its action on the blood contained in the pulmonary artery as well as on that of the veins which surround the thorax. Now, by causing with the help of the currents a forced and exaggerated expansion of the walls, and by multiplying their movements, the air contained in the heart must be sucked in, as happens with the outside air, when the jugular or subclavian is opened. It seems to me difficult to explain this mechanism in any other way; the right ventricle being distended, the tricuspid valves must close the atrioventricular orifice, and consequently the air has no other outlet than the pulmonary artery.

Do the currents directed on the trunk of the nerves themselves exert an action on the movements of the heart?

I don't think so. In this case, electricity acts on the lungs, whose particular sensitivity, when brought into play, determines by reflex action the exaggerated dilation of the chest walls.

As the entry of air into the veins during the transfusion almost always takes place when the surgeon is obliged to choose the jugular to perform this operation, I wanted to verify experimentally whether it would not be possible to combat this accident by *extracting* excess air from the heart. Magendie had given this advice to the surgeons. An experiment, repeated several times, has always given me a negative result; it has made it possible to remove a certain quantity of air from the right ventricle. Nevertheless, it remained without any influence on the fatal ending. It has always been so.

II. *Defibrination of the blood*. – Another objection has been made to transfusion as serious as that of the entry of air into the veins. It has been said: "It can produce coagulums in the transfused blood, which, when launched into the vascular system, cause very serious disorders, most often fatal."

Prévost and Dumas, J. Müller and others, by demonstrating that the red corpuscles are the essential part of the blood, inspired the idea of distracting certain harmful or useless parts of it; Dieffenbach and Bischoff, in showing that fibrin constitutes a *toxic* element from one species to another, were led to give the advice of *defibrinating* the blood by beating. We have seen in the article EMBOLISM that the erratic blocks which cause embolic accidents are nothing other than fibrinous coagulums. Thus it is that Brown-Séquard, Panum, Kuster, Leisenrik, Casse, Tassinari, Christoforis, Landois, Worm Müller, de Bélina, resort to transfusion with defibrinated blood.

In France, Italy, and Russia, on the contrary, most of the surgeons and experimenters, Ponza, Albini, Carlo Livi, Gesellius, Hasse, Moncoq, Béhier, Roussel, reject this method.

Should we or should we not defibrinate the blood when we are going to do the transfusion?

Arguments in favour of defibrination. - 1° Fibrin is not an essential part of the blood; 2° in transfusion, it exposes people to dangers more than it procures advantages; 3° it can coagulate in the devices, hence the need to suspend the operation or the possibility of producing embolisms; 4° to prevent coagulation, one is obliged to press the heart too much, then, surprised by a shower that is too sudden, it can stop in diastole; 5° the act of defibrination transforms the venous blood into arterial blood; 6° defibrinated blood is as reviving as natural blood; 7° it can be kept indefinitely in contact with air; 8° it protects against embolisms. As a result, the operation becomes safer without losing any of its effectiveness.

Arguments against defibrination. - These arguments have been especially well summarized by Gesellius (of St. Petersburg), in a succinct and almost aphoristic form. 1° *Loss of time* of at least 15 minutes, caused by defibrination; so that the transfusion will be likely to arrive too late, especially as a result of sudden haemorrhages, asphyxia, etc. 2° *Much less invigorating activity of the defibrinated blood*; which is proved by the fact that a much larger quantity must be injected to achieve success. 3° The opinion that defibrinated blood arterialized in contact with air is comparable to arterial blood is a mistake, for it is only by the process of oxidation which takes place in the lung that the veinosity of the defibrinated blood can be destroyed, and not by agitation. 4° Blood is a collective tissue, defibrinated blood is no more than a portion of blood. 5° We do not know what is taken away from the blood by depriving it of fibrin, Frantz Glénard (of Lyons) considers plasma fibrin as the life-giving part par excellence, as the reserve of red globules. 6° It is more than likely that the manoeuvres of defibrination modify the molecular constitution of the blood corpuscles. 7° Mittler and Gesellius have never had the same success with defibrinated blood between animals of the same species as with whole blood. 8° In the transfusion of whole blood, the corresponding prior depletion is unnecessary. 9° On the contrary, with defibrinated blood, prior depletion is essential; the most appropriate expression for the transfusion of defibrinated blood would be: depletory infusion of a portion of blood (*depletorische infusion*). 10° The defibrinated blood of mammals acts on mammals of a different species almost always as a poison, and kills most often, even in small quantities. 11° On the contrary, the whole blood of an animal of another species acts on the mammal, even in large quantities, rarely in a harmful manner; it is never fatal. According to Magendie, fibrin facilitates the progression of blood corpuscles in the capillaries of the lungs, spleen, and kidneys; so that infarctions of these organs are not to be feared as long as the fibrin is dissolved, but may be shown by the fact of its absence with the defibrinated blood; according to Magendie, the absence of fibrin is one of the causes of serous and bloody transudations in the lung and intestinal canal. 12° Demme and later Mader saw profuse haemorrhages in the intestine, uterus, vagina, after injections of small quantities of defibrinated human blood. 13° The same symptoms – direct and bloody transudations of Magendie – have been observed by various experimenters after infusions of defibrinated blood between animals of the same species. 14° We can grant to whole blood the favourable property that, in profuse haemorrhages, not subject to direct local intervention, such as haemorrhages of the lungs, stomach, intestines, uterus, it acts by its fibrin which coagulates in the haemorrhagic vessels. 15° Defibrination is anti-physiological, contrary to nature, and everything that is contrary to nature must be rejected *a priori*.

To all these arguments against defibrination, Louis Jullien adds another which is acquiring great importance at the present time. "I will add," he says, "that whatever may be the present uncertainties of the theories relating to parasitic germs, we are not averse to admitting that during these manipulations, these filtrations, the blood, by its conflict with the air, its stay in the vessels and its passage through the flannel, has time to take on the numerous germs that exist everywhere in the atmosphere, and may thus contaminate the whole mass of the liquid blood."

Let us discuss these various arguments. As early as 1852 Devay and Desgranges (of Lyons) claimed that "beaten corpuscles are killed corpuscles." Professor Béhier repeated the same thing after them in 1874.

Here are the three arguments in favour of defibrination: 1° Fibrin is not an essential part of the blood; 2° defibrination constitutes an absolute obstacle to the production of embolisms and leaves the surgeon all the time necessary to operate safely; 3° it does not destroy the efficacy of the blood. Of all these considerations, it is important to consider only one which is of really practical interest: *it is that fibrin is a principle which is not useless and which must be preserved, if nothing stands in the way of its conservation*.

All the fears expressed about the rapid coagulation of the blood after it has left the vessels are erroneous terrors, the surgeons who express them have probably operated only with animal blood. In man, in fact, coagulation does not begin until about the fourth minute after the blood has left the vessels.

However, a somewhat experienced surgeon has all the time necessary to operate before coagulums can begin to form. I must add, however, that human blood may exceptionally possess such plasticity that its coagulation begins to take place rather than usual.

At any rate, considered from the experimental point of view, fibrin does not seem to play an essential role in the phenomena following transfusion, which are almost identical, whether or not the blood is provided with this principle.

Remaining therefore in the reality of the facts, I will say: if the reproaches addressed to transfusion with whole blood are almost all ill-founded, those addressed to defibrination are for the most part not of a greater value. By transfusion with defibrinated blood, as by transfusion with pure blood, successes have been obtained in animals and in man that is impossible to cast into doubt. Both methods are therefore good; it is a question of knowing which is best.

The best will be the one that will bring the greatest number of happy results. Out of 250 transfusions reported by J. Casse, in which he noted the cases in which the blood was defibrinated, there were 174 operations performed with *whole* blood, which gave 95 cures, 79 deaths; 76 transfusions with *defibrinated* blood produced 53 deaths, 24 cures. These results demonstrate how much better whole blood transfusion is than defibrinated blood transfusion. These results demonstrate, furthermore, that fibrin is an essential element that plays an unquestionably active role in transfusion and which therefore must be preserved. It can be preserved without fear, if you have at your disposal a good device which will meet the conditions that we will indicate later, among which we must already mention the most important: the *presence of a metal sieve at the outlet opening*.

INDICATIONS AND CONTRAINDICATIONS. – Transfusion being thus freed from the two most serious objections it raised, we can now approach the study of indications. This study will be easy after the clinical history that we have just done. Let us recall the statistics, the details of which will be read in my *Studies on Transfusion* and the summary on p. 98 to 101 of this article; it must serve as a basis for the judgment to be made.

Performed 535 times for very diverse ailments, it has procured 247 definitive cures and 35 improvements, or, consequently, 282 favorable cases. 49 patients experienced no change. Finally 204 succumbed.

As it is generally envisaged, this result would already be sufficient to legitimize the use of transfusion.

The number of successes indeed exceeds that of setbacks.

These numbers, which summarise all of our clinical research, do not exactly represent the truth. To be convinced of this, it is enough to take each group separately and to carefully follow the results obtained. From this examination will result the precise indications of the method.

In the first group, where we placed metrorrhagia occurring either during pregnancy or after childbirth, we collected 117 observations which gave 77 successes and 40 failures. We have seen that transfusion in metrorrhagia having never been used except to prevent an immediately *fatal* outcome caused by too abundant a loss of blood, 10 patients out of the 40 who succumbed had derived this benefit from the operation. Death occurred only as a consequence of complications to which the transfusion was completely unrelated.

There are therefore 10 primitive successes to be added to the 77 others, which brings the happy results to 87.

The proportion between cases of healing and death is therefore in the ratio of 3 to 1.

After such a result, are we not allowed to conclude that not only is blood transfusion perfectly indicated to combat metrorrhagia occurring during pregnancy or after childbirth, but to formulate this much more absolute proposition:

It is no longer permissible for a midwife or a surgeon to let a woman die of metrorrhagia without having had recourse to transfusion.

In traumatic haemorrhages occurring following wounds, surgical operations, and various tumours which constitute the second group, transfusion has still provided happy results, but in fewer numbers than in previous cases. The ratio is 1 to 1.

Roussel says that traumatic or puerperal haemorrhages, acute or chronic, which threaten a healthy subject with immediate death, moreover, form the most indisputable indication of transfusion, it must be attempted even when the injured person breathes his *penultimate breaths*; one should not delay when conventional treatments for haemorrhage prove insufficient; for example, when the brandy *intus and extra*, when the hypodermic injections of ergotine and sulphuric ether used several times, allow, after a temporary excitement, the syncopal state to reappear, and an increasing depression, undoubtedly due to an insufficiency of the blood volume. The ergot, the contractor of the vessels, the ether, a diffusible stimulant, can produce on the vascular endothelium a sometimes energetic action of excitation of the generative force of the globules; but their effects are always essentially fleeting, and these medicines can in no way claim to replace deficient blood, any more than brandy, by momentarily supporting a hungry person, does not claim to replace food.

There is, moreover, a question of hydrostatic balance: the central organs collapse on themselves and are compressed by their own weight, when their structure is suddenly deprived of the blood mass which normally supports it, a compression incompatible with the play and vitality of the organ. – This question cannot be solved by simple intravascular excitation, which, if it revives the genesis of red blood cells, cannot have produced a large number of them before death has occurred. And besides, is not living blood the best, the functional, the natural exciter of the vascular endothelium?

The *blood dyscrasias*, 13 cases, 8 cures, "chloro-anaemia, haemophilia, typhus" by reduction in the number of red blood cells, or by weakening of their colouring and assimilating power, often resist all treatment and constantly get worse, they are then and very rapidly modified in their causes and effects, by the transfusion of plastic blood, full of vigorous globules, which leads to a rapid proliferation of haematoblasts, their transformation into red blood cells.

Mental illnesses. – Certain states of *mental obsession*, of incoherence bordering on delirium, and certain physical and intellectual depressions bordering on or reaching the stupor of melancholic dementia, seem to be caused by profound anaemia and more particularly by cerebral ischemia. Although chronic, and logically seeming to require chronic treatment, these affections have often had a brutal cause with sudden effects that a sudden and very active therapy can make disappear, and, *sublatâ causa, tollitur effectus*. Here are some proofs drawn from Roussel's practice.

1) A 19 year old girl quickly becomes anaemic, until the age of 39 she remains locked up in a dark room and stays in bed for the last seven years, tortured by all the physical, nervous and hysterical accidents that the most serious anaemia can produce. Her intellectual incoherence borders on delirium. A transfusion of 250 grams of her brother's blood suddenly removed this extreme nervousness, and in five days the anaemia and its physical and mental consequences had disappeared. Operated on 5 March and closely monitored until the end of May, she regained perfect health and was able to leave for the countryside, which she saw for the first time after 20 years of voluntary seclusion.

2) A doctor's daughter, aged 20, has been suffering from profound anaemia for 4 years, with oedema and amenorrhea; half analgesic and anesthetic, she neither eats nor walks, she remains indifferent to everything and to herself. A transfusion of 160 grams improves

her general condition very quickly; the digestive, circulatory and uterine functions are restored, memory, intelligence, health, become perfect again. She is a mother today.

3) A 25-year-old man, in the hospital for the insane in Vienna, has confirmed melancholic demented, with stupor, sitiphobia, immobility and indulgence; his pulse is at 40, his temperature at 35.8, his respiration at 20 or 25. With Leidersdorf and Neudorfer, Roussel gave him a transfusion of 300 grams. Immediately the stupor dissipates, he gets up, he speaks, he eats; in a few days he is no longer demented, cataleptic, sluggish, or anaemic. He remained healed in body and mind.

4) A 20-year-old man, at the Bedlam hospital for the insane in London, has had confirmed melancholic dementia for 13 months, with stupor, sitiphobia, immobility and indulgence. Weak pulse at 70, temperature 36, respiration 25, extreme anaemia. With Bucknill and Rhys-William, Roussel gave him a transfusion of 260 grams. The stupor dissipates, he speaks, he finds his forgotten name, he eats of his own accord; he walks. For a month he was much improved, but, left alone and locked in a cell, he relapsed into melancholy. It had been decided to have a second transfusion, but it was not carried out.

5) A 20-year-old man at St. Luke's Hospital for the Insane in London, demented, melancholy, stupid and immobile, receives a transfusion of 60 grams only because he is agitated and makes completion impossible; a little improved physically, he remains in the same general condition.

6) In St. Petersburg, at the hospital for the incurable in Zagarodny, a congenital idiot woman receives a transfusion of 160 grams, with no other result than a fairly marked physical improvement. A man, a general paralytic, received 180 grams of blood without results, but without disorders. An idiotic woman, very anaemic, was transfused with 60 grams of *venous blood from a sheep*. She seemed a little less sagging. The urine showed albumin, but no haemoglobin or blood in nature, as has often been seen after transfusions of sheep blood, Hasse and others. No doubt there was tolerance for this low dose, then slow and harmless elimination (1874).

As was easy to predict, the effects of congenital malformations of idiocy cannot be ameliorated by transfusion. This will undoubtedly be the case in all cases where mental alienation is accompanied by material lesions of the surface of the cerebral convolutions.

In certain cases of melancholy dementia, Mairet (of Montpellier) observed, at autopsy, slight cerebral malnutrition limited to the convolutions which form the posterior lip of the fissure of Sylvius and that of the hippocampus, and he believes that he can attribute to this region of the brain the creation of ideas of sadness. But are these lesions pre-existent to the alienation, or are they only the late results of a prolonged functional disorder?

Ordinarily, the most meticulous necropsies of the insane who died before the decline of the general paralysis find no material lesion that could explain the delirium: therefore there was only a functioning disorder in a healthy organ. A disturbing external cause or a passionate sensation produces a spasmodic state on a healthy organ, or rather a partial paresis of the vasomotor system, resulting in vascular contraction and local ischemia (pallor). An anaemic organ first loses its functioning, then, if the anaemia is prolonged, the organ atrophies by slow starvation, followed by under-nutrition; the functional disorder thus produces a more or less late material lesion.

If, before the irremediable material lesions have been confirmed, a sufficiently energetic and profound therapy cures the anaemia itself or removes the suspensive cause of the vasomotor function, the body will be able to regain its nutrition and resume its normal function.

It will be noted in groups 1 and 2 that transfusion in doses of 250 and 160 grams cured both chloro-anaemia and incipient stupor, and nervousness with intellectual incoherence. In case n° 5, the 300-gram transfusion definitively cured the extreme anaemia and confirmed melancholic dementia. In case n° 4, the 250-gram transfusion momentarily improved anaemia and melancholic dementia. In case n° 5, a transfusion of 60 grams was ineffective against extreme anaemia with melancholic dementia. In group n° 6, transfusions of various doses of blood from various sources had no effect on subjects affected by congenital malformations and others by cerebral material malnutrition (softening of general paralysis).

From which we can perhaps conclude:

1) That certain chloro-anaemias produce intellectual obtundation and incoherence, without brain lesions – and that transfusion can cure them;

2) That certain subjects, affected by melancholic dementia with confirmed stupor, are not yet suffering from material lesions and suffer only from cerebral anaemia suspending the functions of the brain, both from the intellectual point of view (stupor) and from the physical point of view (immobility);

3) That it is possible that transfusion may cure these subjects of their stupor and immobility, since it cures them of their anaemia;

4) That in order for transfusion to produce and maintain its therapeutic effects, it must reach doses commensurate with the seriousness of the general, bodily and mental state of the subject (Roussel).

The results obtained to date by Italian physicians in the treatment of lypemania are sufficiently encouraging to urge the alienist physicians to enter widely and seriously into the path which has been opened to them.

In malarial cachexia and scurvy, the cures obtained have shown the serious advantages that can be derived from the use of this method.

To all these indications is added another which is sometimes very precious. Often a surgeon placed in the presence of a patient whom he is to operate on hesitates in consequence of a state of weakness such that the operation has only quite uncertain chances of success. The transfusion carried out at that time was able to raise the strength and give the operation a happy outcome.

Béhier rightly points out that transfusion can be of the greatest service in the hydrohemia that follows certain serious ailments, such as typhoid fever, for example.

In the three classes of anaemia which I establish as follows: 1° anaemias occurring as a result of nutritional disorders; 2° anaemia produced slowly by repeated blood loss; 3° anaemias produced by prolonged suppurations, here are the results of the statistics.

In the first class, the successes are in the proportion of 2 to 1; in the second 3 to 1; in the third, on the contrary, failures dominate, they are, in relation to favorable results, in the proportion of 2 to 1. There is a fourth morbid state in which this method has given results that are no less happy: it is in poisoning in general, but especially in poisoning by carbon monoxide and phosphorus. The effectiveness of transfusion in poisonings depends a lot on their degree of intensity. The first degree is that in which intoxication can be overcome by ordinary stimulants. Thanks to them, it is possible to maintain the influence of all the centres during the time necessary for the elimination of the toxic element, and thus to bring back the play of functions. In the second degree, which is much more serious, the action of the poison is carried directly on the blood globules to the point of removing their physiological influence. There is then a cessation of the main functions, without extinction of organic excitability. The last degree, the most serious, is that where we have, in addition to the death of the globules, the complete extinction of all excitability.

Transfusion has the role of combating poisoning in these various degrees, and of stopping the malignant influence of chemical elements introduced into the body.

1° After having tried all other means, recourse should be had to transfusion, because it is not possible to know whether the globules of the intoxicated person have really lost all their physiological potency.

2° A good part of the corrupted blood is to be removed, in order to diminish the power of the toxic agent of the blood which is in the vessels and to give a greater chance of success to the blood being transfused.

3° The injected blood will be oxygenated, so that its action is more rapid and energetic.

In the history of carbon monoxide poisonings treated by transfusion, we have seen that 8 patients had recovered and that 5 had succumbed. Thus this considerable proportion of success has led Casse to say that in carbon monoxide poisoning, the transfusion of blood is, of all the means to be employed, the first to which recourse must be had immediately;

Roussel writes that these poisonings are really amended by the transfusion of pure blood, especially after abundant bleeding both the mass of the diseased blood and the dose of the poison have been reduced. In fact, what remains of the toxic substance is more diluted in a blood made more alive and can be reduced to a non-lethal proportion, while the nerve centres stunned by the poison are themselves revived by the transfused blood.

To better ensure this dilution of the toxic substance, after having been thoroughly bled, he does not hesitate to mix with the transfused blood 300 or 500 grams of hot, pure, alcoholic or medicinal water.

An intermittent *electric current* conducted by a stream of transfused blood was able to operate the heart of a man whose head had just been crushed. Consequently, in many cases of very apparently real death, the exciting and direct effect on the endothelium of the heart of electrical intermittencies must be added when transfusion is attempted. The positive pole of a battery can easily be connected to the bloodstream via the lancet stem of the transfusion recipient.

Inanition caused by an obstacle to swallowing and the absorption of food is a real indication for transfusion, for, when all food has become impossible, one can still usefully prolong life, while waiting for the great maybe.

Despite its often powerful action, transfusion will never produce anything in the final periods of cancerous and tuberculous affections. Would it be the same if, as soon as the first symptoms appeared, the application of this method was carried out with caution and if one sought by repeated transfusions to modify a body tainted by an original defect?

There is here a subject of experimental studies which could become fruitful in its results and which I content myself with indicating: to develop cancer and tuberculosis in animals and to combat them with transfusion as soon as the first manifestations of the disease appear.

CONTRAINDICATIONS. – Organic diseases of the heart, lung and kidney seem to logically contraindicate transfusion, because of the dangers of immediate ruptures or vascular engorgements to which they predispose. I mean a danger of sudden death, because, if it is only a question of aggravating an old disease, it seems to me to be of little weight when it is a question of choosing between a possible survival, or an imminent death by current haemorrhage.

Are generalized diatheses (cancerous, scrofulous, scorbutic, etc.), deep, purulent (septicemia) or virulent (rabies, glanders, syphilis) cachexia contraindications to transfusion? The answer cannot be absolute.

The facts demonstrate that transfusion has cured scorbutics who have fallen into the stagnation of the last period, and also that scrofulous patients suppurating everywhere, and wounded prostrate by hectic fever and by chills of purulent infection, have been wonderfully and for a long time improved. Cancer patients, whether or not they have reached generalized cachexia, are threatened with imminent death by active or passive hemorrhages flowing from an injured organ. Should we let them die because they are cancerous and transfusion will not cure their cancer? And besides, is it absolutely certain that some organ inaccessible to direct investigation is really affected by cancer? Diagnosis and prognosis are not always easy to establish on unshakable bases, and it is only recently that Professor Rommelaere, of Brussels, has just demonstrated a symptom which appears to be the most certain. Roussel sums it up thus: Between two cachectics that seem to have reached the same degree of stagnation, this one is curable, whose urea is maintained at 30 grams per twenty-four hours, the other is incurable, whose dose of urea drops to 10 or 6 grams per day.

So, all other things being equal, the transfusion will only be really contraindicated for the first of these patients. As for virulent cachexias, it seems to me to be a real contraindication to transfusion, for the simple reason that, since the body is infected in its entirety by a poison (virus, miasma or ferment) which reproduces itself in the blood, the toxic dose cannot be reduced, nor, in the present state of our knowledge, can we hope to eliminate the cause of

the toxic proliferation, so that the transfused blood would be immediately altered on contact with the poisoned blood and organs (Roussel).

As for tetanus, the essence of which is still unknown to us, I have seen a transfusion clearly suspend the attacks for a good number of hours.

OF THE VARIOUS METHODS OF TRANSFUSION. – Transfusion can be performed in two ways: either directly (immediate transfusion), by bringing the blood from the vein of the person who supplies it into the vein of the person receiving it, or indirectly (mediate transfusion), by receiving it beforehand in an open vessel, before injecting it.

Roussel admits two other kinds of transfusion:

1° Transfusion of blood conducting an electric current through the device: *electrified transfusion*;

2° Immediate transfusion of blood mixed with pure or medicated water in defined quantities and doses: *infusory transfusion*.

Among all these methods, there is one that Roussel (of Geneva) does not mention and on which I must dwell. This method was first expounded at the Congress of Bordeaux, by Alphonse Guérin, under the name of *Community of Blood*. What does it consist of? Instead of injecting venous blood into a vein with any instrument, says Mr. Guérin, it is necessary to unite, with the help of tubes, the arteries of two beings in such a way that the blood of one passes into the artery of the other, and vice versa. The most important thing is to ensure that the blood passes from the artery of a vigorous animal into that of a weak, anaemic or sick animal. When we act on man, we will in the same way put in direct communication the artery of the one who supplies the blood with the artery of the one who receives it. While the transfusion operated only with a limited quantity of blood, and for a necessarily very short time, I am authorized to think that by operating on the human species I could maintain the community of circulation for several days. The operated on will easily resign themselves to rest, without which the tubes cannot be maintained. They will monitor the aftermath of the operation themselves.

If this is so, if the circulation can become common between two individuals, no longer for minutes, but for whole days, all the blood of one will pass into the vessels of the other and *vice versa*.

Alongside Alphonse Guérin's method is that of Huter de Greifswald (*arterio-arterial transfusion of sheep's blood to man*).

This method was used by Kuster at the Augusta Hospital in Berlin.

Used against typhoid fever, dysentery, cholera, rabies, it has not provided very happy results.

Twice suppurative inflammation of the neighboring joint occurred. This form of transfusion into a human artery offers no benefit. Far from it, it exposes the patient to particular disorders that are added to the disruptive phenomena inherent in the transfusion of animal blood. The blood passes only with difficulty through the capillary circle of the hand or foot; tension, a painful fullness, occurs in the limb, which swells rapidly and is covered with dark red, erysipelatous ecchymotic spots, covering the thumb, hand, forearm.

Béhier expresses himself as follows on Huter's method: "There are already about twenty observations of arterial transfusion, some of which have been successful. Nevertheless, the dangers of an arterial wound, especially in a debilitated subject, seem to me to counterbalance, and beyond, the more than questionable advantages that could be derived from this new operating method which, for my part, I believe I must definitively reject."

Transfusion from vein-to-vein can be immediate or mediate. When experimenting on animals, the former should always be preferred, because of the rapidity with which the blood coagulates. In man, on the other hand, mediate transfusion is very successful, for, as I have already said, the blood does not begin to coagulate until the fourth minute. We therefore have all the time necessary to operate, if we have a good apparatus, and all possible safety, if we have taken care to place a metal sieve at the outlet opening.

Injections of blood into the cellular tissue. – In the month of October 1873, (Karst, of Kreuznach), put forward the idea of substituting for intravascular transfusion the injection of

blood into the cellular tissue; it was, in a word, a question of treating chloro-anaemia by repeated injections of blood globules isolated by beating and defibrination, pushed into the hypodermic cellular tissue with the Pravaz syringe. Having performed this injection on a rabbit, he had seen the blood absorb with extreme ease. Later Landerberger (of Stuttgart) made a number of experiments on animals and, together with Karst (of Kreuznach), he definitely proposed this method.

But, says Louis Jullien, what becomes of this mass of blood injected into the cellular tissue? How long does it take to disappear? What elimination routes are there? Poncet's experiments will teach us this. The injection under the skin of an animal of a certain quantity of defibrinated blood, at a temperature of 37 to 38°, from an animal of the same species killed at the same time, is most often harmless. The animal is in no way inconvenienced, and the local phenomena are as simple as after an injection of pure water. A few hours after the injection, all traces of a blood bump have disappeared; the blood is gradually gaining ground, filtering a little in all directions. The resorption takes place rapidly, as is shown by the examination, after two or three days, of the blood effusions.

What blood should be used for transfusion? – The blood of the animal has this superiority over that of man, that it is inexhaustible and always ready, that thanks to it, in the interest of a compromised life, no existence will be put at risk.

The lancet perforated the vein: the transfusion was fortunately carried out for the transfused person: but what will happen to the transfuser? Shall we find in science observations which will enable us to answer this question, the importance of which will escape no one? It will most often happen that in a very few days the transfuser will have repaired what he has lost, but is this the same in all cases?

To sum up, animal blood introduced into the vascular system of man has often produced very good effects; *it has never been harmful*. The efforts of clinicians must therefore be directed towards popularizing the method of animal transfusion and bring it definitively into practice.

As to *temperature*, my experiments can leave no doubt as to the uselessness of the precautions taken to preserve the heat of the blood equal to that of the body. These precautions have, on the contrary, the result of bringing about coagulation more quickly. The transfusion should be done *without any concern for the ambient temperature*.

As for the dose of blood to be injected, it varied in the observations previously reported between 30 and 700 grams.

From this point of view, here is the practical conclusion which I believe I must formulate and establish as a principle: *"Low dose transfusion should be performed, repeating it, if necessary"*.

The injection into the veins of a liquid other than living and complete blood is useful only very exceptionally; it is always harmful, if this liquid alters the blood or dilutes it, and if this liquid is liable to produce vascular infarctions.

The transfusion of the blood of an animal of a foreign species is always harmful.

The transfusion of blood of the same species, by indirect, instantaneous, or defibrination methods, is most often harmful.

In all these cases, if the bloodless subject has been revived by transfusion, his survival is never more than very short. The liquids thus injected, as well as the parts of the own blood which have been altered by contact with the liquid, are eliminated in the first hour by the urine, and by all the routes of excretion, and this elimination demonstrates that these substances have been nothing but useless and harmful foreign bodies.

Only the blood of the same species, complete, alive, can ensure the definitive survival of the transfused person; it is not eliminated, and its red blood cells continue to live in the organism that received them. It causes the formation of young blood cells (haematoblasts), which soon become red blood cells.

In clinical practice, in the human species, transfusion of live blood can ensure survival in the following cases:

Acute hypohemia due to recent hemorrhage.

Severe anemia with or without prior hemorrhage.

Poisoning of the blood, if the toxic substance is likely to be eliminated in part by a strong preliminary bleeding.

In fatal haemorrhage, 200 to 300 grams added to the blood remaining in the veins are sufficient to ensure the functions of the heart and brain. In so-called incurable anaemia, chronic hypoglobulia with or without previous haemorrhages, at least 100 grams are necessary to restore sufficient vitality to the debilitated body (Roussel).

Transfusion receives all its value from the method by which it is directed and the process by which it is accomplished; before undertaking it, it is necessary to have learned to handle whole and living blood, without any alteration *in transitu*. No conclusions can be drawn from the old methods which used altered blood as to the indications, doses, or results of the transfusion of live blood, as it must be practiced according to recent progress.

ACCIDENTS OF TRANSFUSION. – The entry of air into the veins, the introduction of small coagulums due to coagulation, the penetration into the vascular apparatus of small solid foreign bodies, constitute the main dangers of transfusion and can give rise to fatal accidents.

J. Casse also reported mydriasis, vomiting and anal tenesmus; a final peculiarity to be noted is the dyspnoea which sometimes occurs during the operation. Since it is usually caused by injecting too much blood, it will be just as easy to avoid as it will be to prevent it from occurring.

EFFECTS OF TRANSFUSION. – We very often observe 20 or 50 minutes after the operation the *shiver*, which Roussel and Casse consider to be constant.

The temperature increases by one degree or half a degree. The pulse quickens and soon becomes fuller. Almost always the transfusion is followed by sweating and subsequent sleep. Urinary secretion increases, but it retains its clarity and colouring, unless the dose of injected blood is too high.

A little headache sometimes persists for a certain number of days.

Roussel describes the phenomena produced by direct transfusion as follows: The direct transfusion of living blood produces during its execution some phenomena, not very marked, of excitation, congestion and dyspnoea; deep breaths quickly make them disappear.

These disorders are due to the still irregular state of overload of the heart and lungs; they are all the lighter, as the supply of new blood is conducted with a rhythm more harmonized with the current state of the heart. It is by the observation of these disorders, and by the understanding of their causes, that Roussel was led to reduce the capacity of his motor balloon to the low capacity of *ten grams*, and to lay down the rule of sending these doses of 10 grams only 3 or 6 times a minute, that is to say, to transfuse only *fifty to sixty grams* per minute.

By operating in this way, the heart of the transfused patient – who is usually a patient with at least 100 beats per minute – only receives an addition of half a gram of blood at each diastole.

The necessity of a relative slowness in the succession of blood waves, together with that of not allowing the blood to remain stationary outside the vessels, leads to the formulation of this second important rule: "Draw the blood from the vein that gives it only as it penetrates the vein that receives it." These rules can only be observed by means of a *direct anastomosis* between the two circulations.

The transfusion is soon followed by a shiver, sometimes moderate, sometimes quite violent, accompanied by concentration, smallness and acceleration of the pulse, while the internal temperature of the vagina or rectum seems to increase; breathing becomes rapid and a little panting.

Although apparently worrying, if one is not warned, - this shiver is not serious, it is temporary and usually unique, not lasting more than half an hour.

The patient should be made to drink sips of hot alcoholic tea, his bed should be heated with hot water bottles and quilts, and prolonged inhalations and exhalations should be recommended.

Soon the breathing resumes its normal type, the shivering ceases, the heat and color return to the skin, and the hot reaction begins.

The shiver and its jolts indicate a disruption of equilibrium, and oscillations of the vasomotor system produced by the influx of transfused blood. By the very fact of their anatomical elasticity, the vessels allow themselves to be dilated, then contract, further dilate, and oscillate to the depth of the organs, under the successive thrusts of the waves of the new blood.

Although produced by an opposite cause, this shiver is analogous to that which accompanies excessive haemorrhages and which, in itself, denounces to the midwife an internal metrorrhagia. The latter is a precursor of death; it indicates the disruption of the balance, in diminishing, of the organs that are emptying. The shiver of transfusion is a precursor of life, indicating the disruption of balance, an increasing, of the vessels that are filling.

The hot reaction proves that the organic equilibrium has been restored in a higher tone, and also that the new blood is beginning to produce the desired effects of vital excitement and reconstitution.

This reaction, which rarely takes more than 20 minutes after the onset of the shiver, is rapidly progressive. The patient shows a feeling of warmth and general well-being; his skin becomes coloured and moist; sweat begins to bead on the forehead, it spreads over the chest, and soon wets the whole body with a warm and pleasant perspiration.

However, the breathing has become slower, more regular and deeper, the voice is sonorous, the eyes are shining, the mind is lucid, the pulse is approaching the normal rhythm, it is full, regular, well struck around 50 or 100. Soon a deep and repairer sleep confirms the success of the operation.

These are the prodromes of the frank convalescence which will be established. After one or two hours, the awakening is usually caused by an urgent need to urinate and defecate. The *urine* of the first days is examined, and it is regularly found that it is abundant, transparent, light straw-yellow, or a little darker, loaded with salts and urea, but *free of protein substances* from the blood, and *albumin*. This proves that the blood transfused directly and *alive* is not a foreign body destined to be eliminated, but that it has become an integral part of the body of the patient; that it remains and circulates alive and well alive in the vessels; that its globules will restore vitality, an organic synergy, ready to be extinguished, and that its plastic fibrin will promote the healing of all wounds. In the urine is the criterion of transfusion (Roussel).

INSTRUMENTS AND DEVICES. OPERATING MANUAL. – In the first class, we will describe those that are intended for immediate transfusion. The second will contain those which are more particularly used for mediate transfusion.

I. *Immediate transfusion device of Roussel* (of Geneva). – In 1867 Roussel compared this apparatus to a new variety of leech, which would have an accessory proboscis on the head and on the forked tail two canaliculated points through which various liquids could be expelled separately.

Through its trunk the leech gorges itself with water, in order to empty itself of air before pricking the skin and sucking the blood; then through one of the tips of its tail it expels the water, so that only pure blood is sent through the other caudal tip. A suction cup, encircling the mouth armed with two teeth, attaches it to the skin above the vein of a subject, and a hook fixes in the vein of another person the caudal point from which the blood gushes. Thus placed, this transfusion forms a direct anastomosis between the two circulations; which is the ideal to achieve.

To satisfy the minute necessities of direct transfusion, the operation must take place entirely away from air, in the interior of a closed instrument full of water. The operating manual, without being difficult, is delicate and meticulous, because the blood itself is of extreme delicacy.

FIG. 12. – Position of the subjects for direct transfusion.

Position of the characters for the direct transfusion of blood. – The face and chest of the woman, which we suppose to be bloodless, are uncovered, in order to show the respiratory movements; her right arm, pulled from the bed, is lying supinated on a narrow table. The man is sitting on the other side of the table; his supinated right arm is extended parallel to that of the woman. On the table is a vase containing hot water with a small quantity of baking soda ($^{1}/_{1000}$); the vacuum tube of the transfusor, previously checked, washed and heated is immersed in this water.

The surgeon standing in front of the table, with the woman on his right, the arms of the two subjects resting in front of him, his tools: scalpel, forceps, erignes, scissors, bandages, compresses, sponges, at hand, is in the most comfortable position to operate well. But usually the transfusion is of such urgency that you have to know how to do without all comfort. A few days ago a woman suffering from a series of haemorrhages had just given birth on a bed of very low misery: I had to make the blood donor sit on the ground, his legs slipped under the bed and supporting the water pot himself. Pressed against the wall, I was on my knees, with the bloody cloths and the dead child under me. Without space, without sufficient light, without aids within reach: a happy transfusion was completed in a few minutes.

It is in these cases, the most frequent, that the need for a rapid method and an instrument that can be used without impedimenta or assistance.

Preparation of the vein to be transfused. – After profuse haemorrhages and in deep anaemia, the superficial veins are so retracted and effaced that it is most often impossible to distinguish them through the fleshy and thick skin of the arm. To say that a trocar must be plunged, through the skin, into this vein whose position is scarcely suspected and whose diameter is unknown, would expose the majority of practitioners to failures of which examples are all too numerous.

And besides, I do not admit either trocars or metal cannulas, knowing from long experience that the blood coagulates very quickly in a metal tube, and that it obstructs it in a few moments by concentric layers of solid fibrin.

The vein must be exposed and opened, without, however, dissecting it through the posterior part, without passing a probe or ligatures under it.

It is urgent to make the vein temporarily turgid with blood, so that it is known where to make an incision in the skin, but it is also necessary that no significant quantity of the blood of this already bloodless subject can be lost.

FIG. 13. – Arm of the subject to be transfused

1st time. – Wrap the hand and forearm up to the elbow in the tight turns of an ischemic elastic band. All the blood remaining in the veins is thus pushed back, and the circulation is now interrupted.

Place a tight tie on the biceps, above the elbow. This results in turgor of a section of the median vein and at the same time ischaemia of the arm. When the vein is opened to insert the cannula, only the few grams of blood trapped in the venous section between the two bands will flow out. This blood being sponged, the operating field will no longer be masked and the surgeon will be able to *a sec*, at ease and without haste, safely introduce the cannula into the open vein (fig. 13).

2nd time. – Incise the skin, raised by a transverse fold, above the turgid vein, separate the cellular tissue of the sheath, prick the upper wall of the vein with the tip of a fine hook (cataract erigne), lift the vein, and with pointed scissors cut obliquely a V-shaped flap which remains attached to the hook and rises like a lid; this flap serves as a faithful conductor for the cannula.

This time of penetration of the cannula into the bloodless vein has always been noted as one of the difficulties of transfusion, whatever the general method of the operation.

To make it simpler, Roussel had a small tool made in St. Petersburg which was adopted by Russian surgeons.

It is a *sandfly dilator*, one of the bits of which is prickly and sharp, while the other is blunt; applied one on top of the other, when the tool is closed, they together form a regular point (fig. 14).

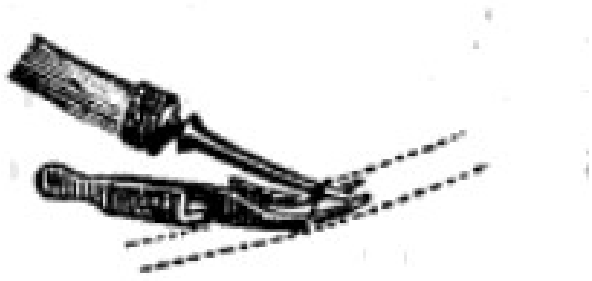

FIG. 14. – Conductive sandfly of the cannula.

It is thus plunged into the exposed vein, then by pressure on the branches the jaws are pushed apart, which dilate the opening of the vein, and leave between them a perfectly certain path for the passage of the cannula. The cannula, once introduced into the vein, sinks freely up to its heel.

Whether it was a cannula or a trocar, depending on the method, it was formerly necessary to take care that it did not come out of the vein, that it did not close by the application of its orifice against the venous wall, and finally that the patient's blood did not escape through the lower end of the vein, and that the transfused blood is not lost by a retrograde flow.

An assistant is usually dedicated to these delicate functions. Roussel has tried to do without this assistance, which he has sometimes found more annoying than useful and which is often lacking, and for this he has fixed a large *clamp* to the heel of his cannula with which he pinches the skin by bringing the lips closer to the incision: he thus compresses the vein on the cannula it contains, prevents any blood loss and securely holds the cannula *in situ* (fig. 13).

When the donor's blood is ready to come, the ischemic band from the forearm is quickly unwound and the tie placed on the biceps is untied. Circulation is immediately restored in the limb.

For a *blood donor*, one should prefer an adult man, healthy and vigorous, with well-muscled arms and protruding veins; yet I have not had to repent of having several times taken blood from the arms of devoted women, though of feeble appearance. On the contrary, we have seen several times husbands unable to bear, not the bleeding which they did not feel, but the sight of their wives dying and subjected to the preparations for the operation.

We will not admit a man obviously tainted by a contagious or hereditary affection, unless, however, the urgency of the danger of death leaves not a minute to lose; when it comes to imminent life or death, the possible danger of contagion is of little importance. We will prefer an intelligent man, who can reason his actions, to a vigorous boor who will faint when he sees the dying person come back to life.

The serious necessity of sparing the nerves of the blood donor will favour the transfusion process, by which the blood flows without being exposed to the view.

In hospitals, it is wise to impose on students, blood donors, two days of absence from the department, until the bleeding has completely healed.

To operate, the surgeon carefully checks and traces in ink the path of the humeral artery, which must not be injured (towards the bend of the elbow, one feels the artery beating under the inner edge of the biceps, and becoming more superficial by crossing the median basilic vein, to become deep again under the muscles of the forearm), then the arm is compressed, to the lower part of the biceps, by a tight link, which stops the venous circulation and makes all the veins turgid (fig. 16). We are looking outside the line of the artery, a clearly visible radial vein, preferably the origin of the radial vein, usually marked by a swollen nodule, or the upper part of the cephalic median, and the point chosen for the bleeding is marked in ink. The surgeon then takes the transfusion; by compressing the *balloon* attached to the tube (A) of the *suction cup* (V), it adheres the latter to the skin, so that the bleeding point (*v*) is visible in the centre of the internal *cylinder* of the suction cup, and he spreads over the arm the flexible edge of the *wet balloon* (*b*) which, moving the air away from the edges of the suction cup, ensures that the latter is unshakably fixed, despite any movements of the arm (fig. 15).

In choosing the vein to bleed, the surgeon was able to appreciate the thickness of the skin, as well as the depth to which the lancet must penetrate in order to make a large bleeding; on this data, he unscrewed the millimetre screw head T (fig. 15) of the lancet, and lengthened the course of the latter outside the cylinder in which it plays. He then closes the cylinder by adjusting the *lancet holder* (P) like a cork ground with emery.

The two metal eyes (R) placed at the head of the lancet holder indicate the plane of direction of the blade, which must be placed transversely to the line of the vein.

The lancet (L) of the transfuser is bifurcated, it represents two triangles looking at each other through their hypotenuse lines, which are the only sharp ones. This blade descends to place itself astride the vein (*v*), of which it incises the two lateral walls and the upper one, without ever being able to reach the posterior wall. This lancet shape makes it possible to make an incision large enough to provide an abundant stream of blood for a long time, whereas, if one wanted to obtain such a bleed with the classic lancet, the point that

penetrates first would cross the diameter of the vein, and would prick or cut the posterior wall by completing the section of the vein; which must be avoided, because an *incised* vein scars and remains permeable, while a *severed* vein is blocked at both ends. The lancet blow is scarcely felt, because it is given under a layer of hot water penetrating through the tube E and by a heated blade.

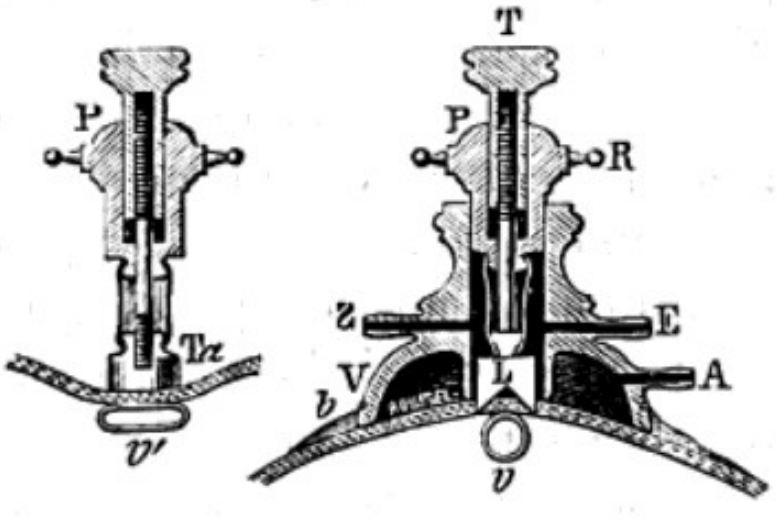

FIG. 15. – Details of Roussel's suction cup.

Bleeding is carried out by a sharp blow on the head (T) of the lancet (L); this head comes up against the blade holder (P), and the lancet cannot exceed the depth that has been fixed to it by means of the millimetre cursor (T). The blade rises to the top of the cylinder, the blood drives out the water and flows through the tube (S) into the motor balloon.

For greater caution, bleeding is not done all at once: first the blade is given enough travel only to cut the skin, then the cursor is unscrewed by two millimetres, the blade goes back through its first path and attacks the vein; if the blood comes in sufficient abundance, it is left at that, even if it means lengthening the blade a little longer and enlarging the incision during the transfusion, if the vein, by deflating, returns on itself and reduces the passage of blood.

When the transfusion is completed, the surgeon lifts the suction cup, quickly places his left thumb on the stream of blood, and with his right hand he wraps the arm in a simple figure 8 band, under which he has placed a small pad of carbolic cloth. The blood donor is dismissed with thanks and a warning not to make violent movements with this arm, the incision of which will be healed in a few hours.

Bleeding by hand. – Some surgeons may prefer the execution of the bleeding to the classic way; to satisfy them, Roussel provided the transfuser with a spare part. It is a *buffer holder* (P) with which the lancet holder in the cylinder is replaced. The pad (T*a*, fig. 15) can extend to the lower orifice of the cylinder and touch the skin, it is fixed in this position by means of a bayonet nail; when it is unhooked, it goes up to hide in the top of the cylinder. The surgeon performs a large bleed with his free hand, immediately caps the jet with the suction cup by closing the pad, which presses on the bleed (*v'*) and stops the jet of blood, as would the tip of the finger. Then, when the operation of the water is completed to expel the air, simply unhook the buffer to let the blood intended for the transfusion flow out of the vein.

The current of water. – When the transfuser has been secured to the arm of the blood donor, by suction of the suction cup, the instrument is full of air; if the blood were brought there, it would *bubble* in the air, and the fibrin, altering in less than two seconds, would adhere in the form of clots against the dry *walls* of the instrument. This fatal coagulation of the blood in a dry instrument full of air has been the insurmountable obstacle to all my predecessors. It caused sudden deaths, by embolism, which caused transfusion to be condemned. It was this that inspired the idea of defibrination, a practice contrary to all

physiological notions. It even occurred in transfusions of arterial blood from animals, operated with a simple tube of a few centimetres.

Clotting occurred even faster when the blood was collected in a basin and taken back into a syringe. It occurs with more modern instruments, in which the bowl transformed into a funnel is adherent to the syringe. Blood clotting occurs more rapidly in a vacuum than in the open air; it is inevitable in instruments that are sought to empty of air by the lifting of a pump piston.

If, however, a good number of successful transfusions have been accomplished, it is because very small doses of blood were used, which could be injected before coagulation was complete, and also because certain individuals, probably haemophiliacs, had blood more resistant to coagulation; in any case, it is remarkable how few authors have been able to make their successes known; most of them have succeeded only once, they have failed later, by coagulation, when they wanted to reach higher doses, or by insufficient results, when they have remained at their small doses.

The former instruments were dry and full of air, moreover they were constructed of metal and glass, and these bodies have such a catalytic effect on the blood that at first contact the blood adheres to the walls and varnishes them with a coagulated layer. This effect, though delayed, still occurs, even when these metal and glass instruments have been, according to my method, emptied of air and primed with hot water.

Natural rubber, unsulphurised, elastic or hardened, is a neutral body, a good caloric preserver, which, being wet, has the smoothness, softness and polish of a venous tunic; it lets the blood slide without altering it. That's why the transfuser is made entirely of natural rubber, with no glass parts or metal trocars. These are the reasons why it is traversed by a current of hot water which takes the place of the air, wets its walls and heats them, so that the blood retains intact its proper temperature. But this water must not be injected into the patient; it is discharged through an outlet tube (6, fig. 16).

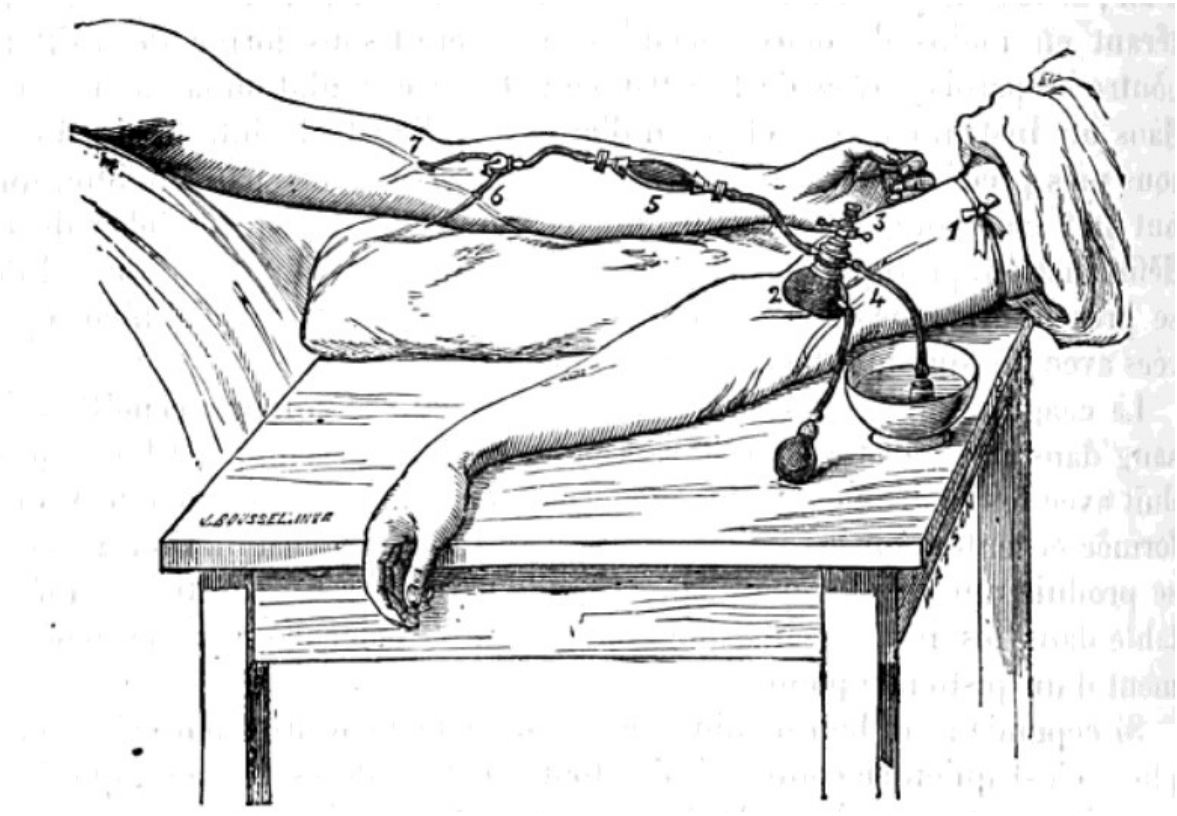

FIG. 16. – Roussel's Transfuser

When the transfuser is fixed above the blood donor's vein, and when the lancet is in place, threatening the vein, the aspirating tube (4) is immersed in a vase containing water raised to 40° with the addition of 1 per thousand of baking soda and intended only to properly purify the instrument.

By the operation of the motor balloon (5) the water is sucked in, it fills above the vein the cylindrical space in which the lancet plays, it fills the motor balloon, it expels the air and flows out through the bifurcated tube, one branch of which carries the afferent cannula (7) and the other carries the outlet tube (6). The surgeon inserts the water-dripping cannula into the vein of the transfused patient and closes the heel of the cannula (1) by means of the clamp placed at the angle of the bifurcation.

The two subjects are at this moment united by an anastomosis full of water and impenetrable to the air. It is then that the surgeon bleeds the blood donor. The blood chases the water before it, just as the water had chased away the air, it comes out through the outlet tube (6) and, when the blood appears pure and coloured, this tube is closed with the hook of the clamp, which gives free passage to the blood into the cannula already insinuated into the vein of the transfused.

The anastomosis currently unites the two blood circulations; it carries in its middle an artificial heart equipped with valves and capable of diastole and systole movements. Each beat of this balloon-motor extracts 10 cubic centimetres of blood from the donor's vein, and immediately sends this dose to the transfused. The heart of the transfused person beats 80 or 100 times per minute and we should only send him 5 or 6 doses of 10 grams per minute, i.e. less than half a gram at each beat. This very minimal overload preserves the patient from any cardiac or pulmonary congestion. With each stroke of the motor balloon, the vein of the transfused person is seen to swell and undulate to the armpit; ascending friction can be made on this vein, to facilitate the progression of the blood at the time of completion of the operation. When the entire dose required by the patient's condition has been transfused, the fine clamp that pinched the skin is opened, the cannula is removed from the vein and the arm is bandaged with a figure 8 bandage: the transfusion is accomplished.

DIRECT TRANSFUSION OF ANIMAL BLOOD. – *Operating manual*. – Bind the animals separately on portable planks with holes. Make an incision in the skin, shaved, near the crural arch, to expose the vessels, pass under each of them three waiting threads for ligations. Empty the transfusion of air by filling it with hot sodium water (baking soda $^{1}/_{1000}$) by means of the vacuum syphon (1) primed by the motor balloon (2). Take the bloodless animal to be transfused; insert the afferent cannula (3) filled with water into the central end of his saphenous vein, fix it by the fine clamp pinching the skin, close it by the bifurcation clamp (4), the outlet tube (5) remaining open (fig. 17).

Approach the blood-donating animal, insert into the vessel the efferent cannula (6) full of water, fix it by the clamp, close the siphon with the clamp hook (7) at the bifurcation. The blood enters the instrument, it drives out the water which flows through the outlet tube (5). When the blood is pure at the outlet, close the latter by turning the hook of the clamp (4) over, which opens the passage of the blood through the afferent cannula into the vein of the bloodless animal; tighten ligatures on vessels that are losing blood; maneuver the motor balloon (2) from which the diastole sucks the blood and from which the systole pushes it out in regular doses of 10 cubic centimetres. The use of the balloon is essential for the transfusion of venous blood, which has no impulse of its own, its use is necessary for the transfusion of arterial blood, in order to count the dose, and especially in order to regulate the speed of the transfused current according to the movements of the animals' hearts.

For the transfusion of venous blood, the efferent cannula is placed in the peripheral end of the donor's saphenous vein. For the transfusion of arterial blood, the cannula is placed in the central end of the femoral artery. The results are the same regardless of the source of the blood; as soon as it reaches the lungs the venous blood becomes arterialized, and conversely the blood sent arterial becomes venous in the capillaries: there can therefore be no legitimized preference for arterial blood. On the other hand, the veins into which one transfuses are made to contain venous blood, and, as the injury of an artery is more serious

for the blood donor than that of a vein, the preference for the transfusion of venous blood is doubly justified.

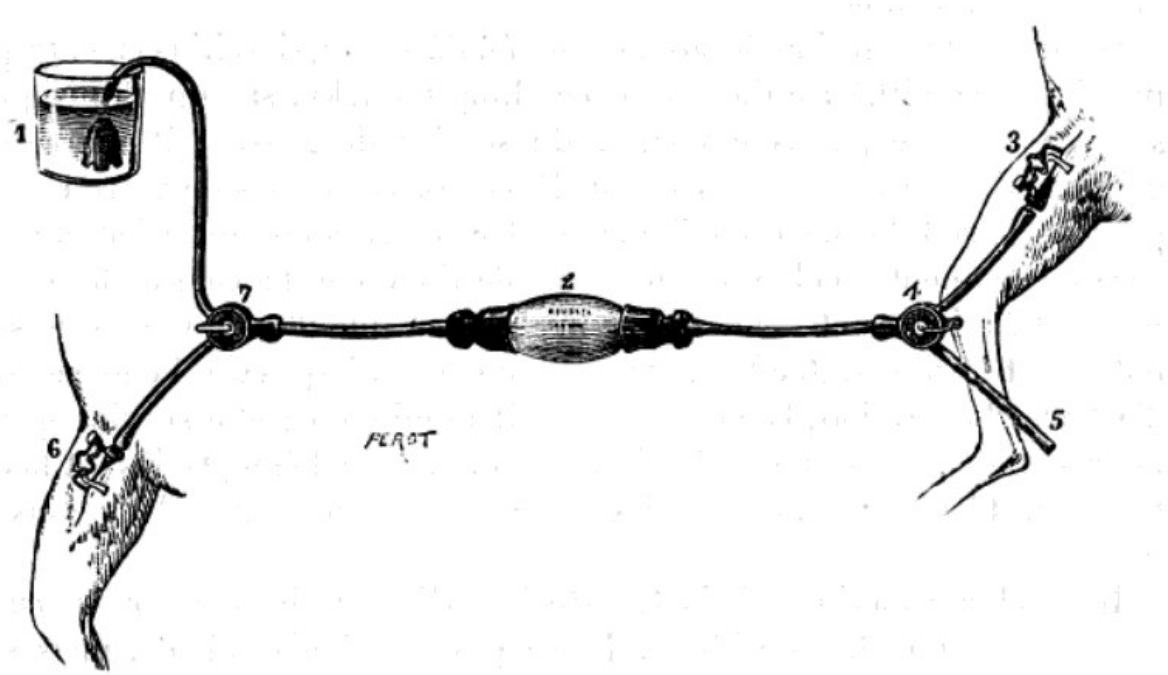

FIG. 17. – Roussel's direct transfusion for animal blood.

In 1874, a competition was opened by the Faculty of St. Petersburg between the various methods of transfusion. O. Heyfelder performed two good direct *arterio-venous* transfusions from man to man. Roussel operated a large number of *veno-venous* transfusions from man to man.

As for the transfusion of *animal blood to man*, Gesellius undertook one in the amphitheatre of the surgeon Korjeniewsky, on a phthisic with indurated tops, without caverns, in Besser's service; he used Hasse's direct arteriovenous method. Two glass cannulas joined by a short rubber tube establish communication between the carotid artery of the sheep and the median vein of the man. The current was open for 2 minutes and half minutes. Gesellius estimated that 200 grams of blood had been transfused. Frightful phenomena of asphyxiation prevented him from completing the operation, death seemed imminent; it occurred four hours later, in increasing asphyxia, with haemoptysis and haematemesis. The autopsy showed haemorrhagic foci in all the organs.

Roussel experimented with the *direct* transfusion of sheep's *venous* blood on an idiotic woman. It did not cause any accidents, but only transient albuminuria. There was a slow elimination, which did not cause the serious disorders in the kidneys that are usually observed after transfusions of blood of different species.

Roussel also performed a transfusion of *sheep arterial* blood, in large doses, 240 grams, on a dying man in a coma of agony, by pyohemia, in the Korjeniewsky's department. The flow of blood coming through the animal's carotid artery could hardly be moderated, no serious disturbing phenomena occurred, on the contrary, the dying man regained consciousness and was able to speak and move with vigor. The tumultuous pulse rose to 120, all the superficial veins became very apparent and swollen, three hours later his body became cyanotic and covered with haemorrhagic petechiae, which were seen to form especially on the belly and around a large phlegmonous wound covering caries of the iliac bone. He had increasing dyspnoea, involuntary bowel movements, and clear, non-bloody urine. No shivers. Ten hours after the operation, he relapsed into the agony from which he had been drawn, and died at the thirteenth hour, without any particular phenomenon. The autopsy showed multiple bone caries with abscesses by transport of pus, and organic

degeneration of the lungs, liver, spleen, and kidneys, which had been diagnosed, and in addition, numerous capillary haemorrhages, but without foci, in these degenerated organs, and in the whole wall of the belly. The blood was clear and coagulum-free throughout the body.

The capillary haemorrhages could only be attributed to the foreign species of sheep's blood, for nothing of the kind has ever been observed in direct transfusions of human blood, even in larger doses, 280 to 320 grams.

After the competition, Roussel's direct method was approved by the Academy of St. Petersburg, and the transfusion became part of the arsenal of civilian hospitals and the army. It was with Roussel's apparatus that Hayem carried out his latest experimental researches on animals, especially those in which the increase in the number of globules was uninterrupted and increasing from the day of the transfusion. This method imposes a minimum loss on the blood donor, and provides maximum certainty for the desired results, because the blood is transfused alive, without alteration.

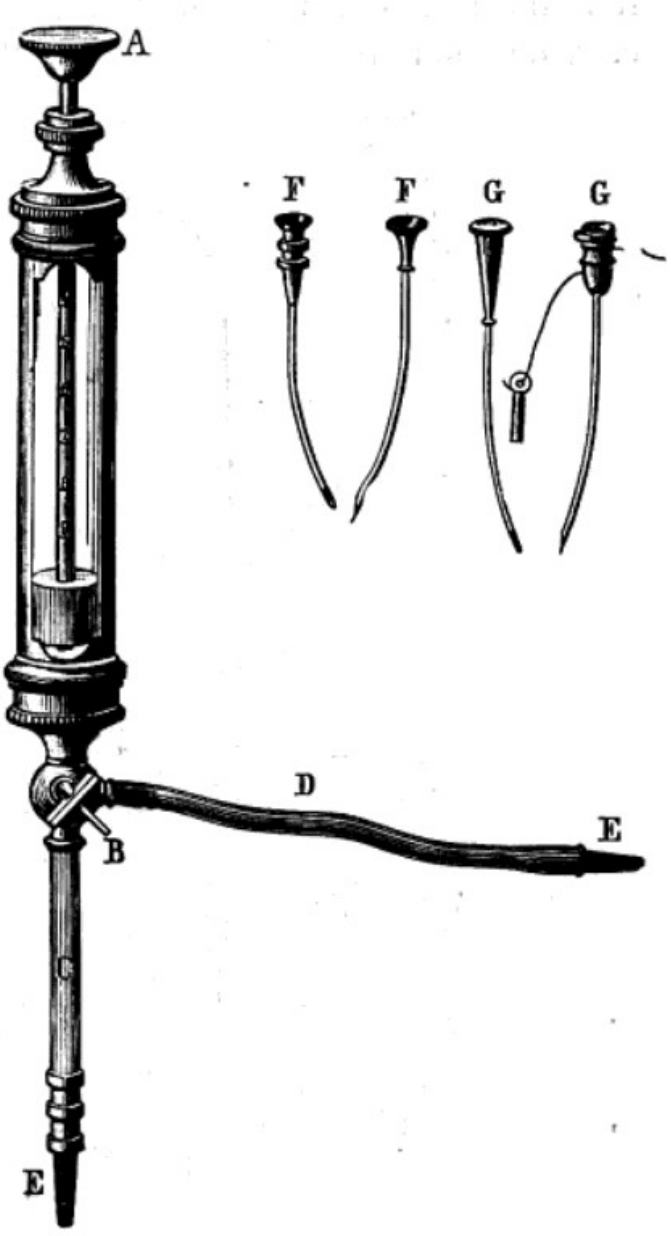

FIG. 18. – Instrument by Manzini and Redolfi*

* A, pump; B, double-outlet valve; C, elastic suction tube; D, elastic treading tube; EE, metal tubes surrounded by silk threads; FF, cannula and hairpin; GG, cannula and pin for the vein and artery of the transfusing animal.

This device consists of a pump body in which a piston slides. The pump body is articulated at the bottom with a nozzle from which two tubes, one vertical, the other horizontal, originate. The first is intended to enter the vein of the animal that supplies the blood; the second in the vein of the one who receives it. When the pump body is filled with blood, simply turn the valve so that the opening which makes it communicate with the outlet tube is free; the plunger is then pressed and the transfusion takes place. In order to prevent clotting, Manzini and Rodolfi soak the tubes in an alkaline liquid for twelve hours. I must say that this precaution is absolutely unnecessary.

When, instead of performing immediate transfusion from artery to vein, it is done from vein to vein, the heart pressure, which is noticeably lowered, is hardly felt: therefore it has been thought of replacing it. It was in this order of ideas that Manzini and Rodolfi had their apparatus built (fig. 18).

I content myself with mentioning the apparatus of Le Noël presented to the Academy of Medicine in 1874 and that of Collin, both very ingenious.

Devices for mediate transfusion. – With these devices, transfusion can be carried out by two processes: 1° with defibrinated blood; 2° with whole blood.

Among the devices intended for transfusion with defibrinated blood, there are three which present a certain analogy to each other; these are those of MacDonnel, J. Casse (fig. 19) and Belina.

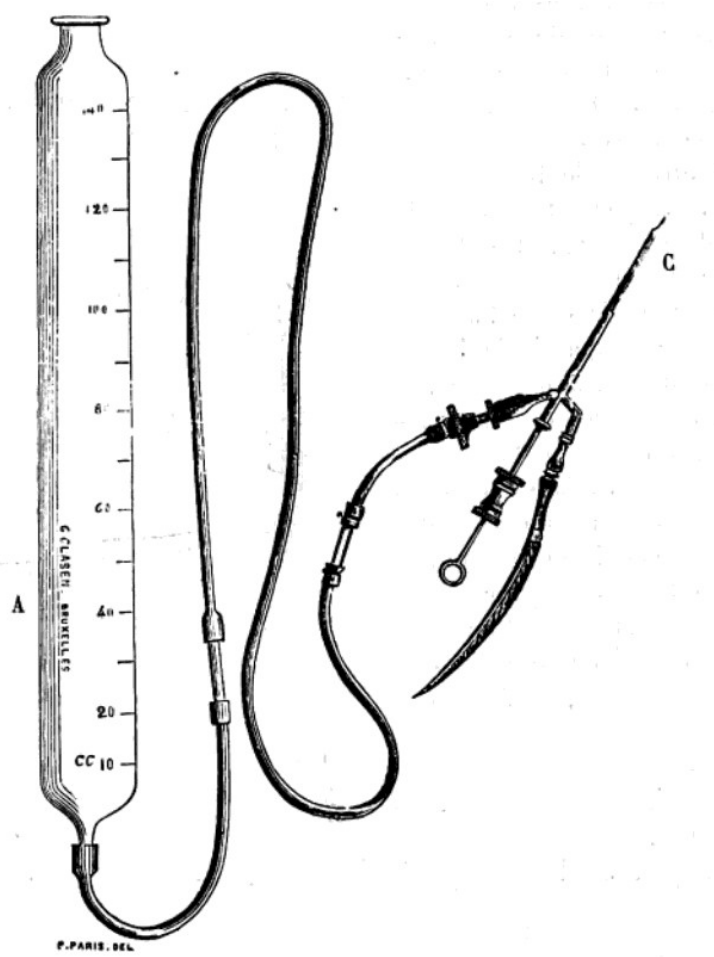

FIG. 19. – Apparatus of J. Casse*

* A, graduated container for receiving defibrinated blood; C, cannula for puncturing the vein.

I had the opportunity, at the time of the Brussels Congress (1875), to see J. Casse's apparatus, and to hear this colleague describe it himself. This device is very simple, very ingenious, and easy to handle, but it can only be used for transfusion with defibrinated blood. Starting from the physiological fact that, the pressure in the veins being excessively low, only a minimal force is required not only to balance it, but to easily overcome it, by increasing the external pressure somewhat, the internal pressure being overcome, the liquid enters the vessel.

I am now able to speak of the devices with which both immediate and mediate transfusion can be carried out, these are the devices of Moncoq (of Caen) (figs. 20 and 21).

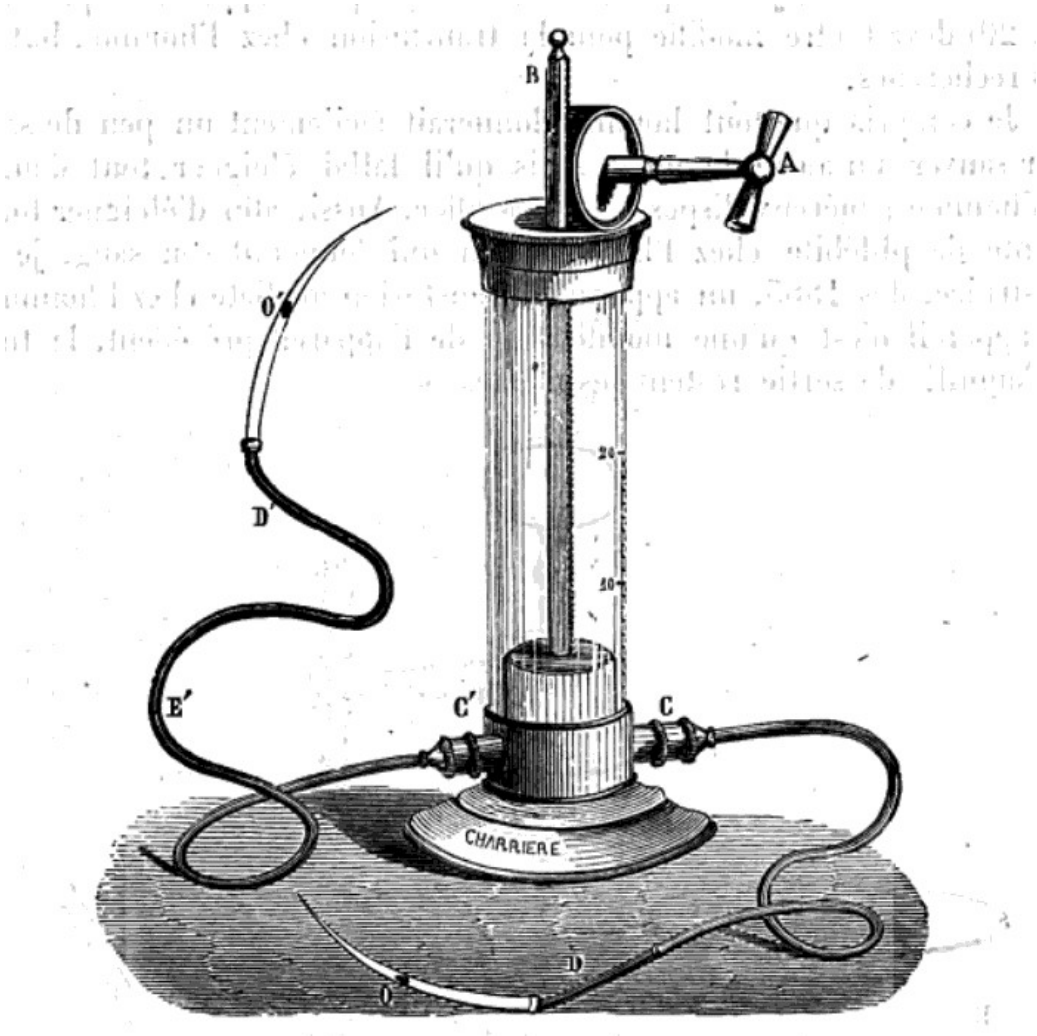

FIG. 20. – Moncoq's first device *

* A, handle to set rod B in motion (the cylinder of the middle part is made of crystal; it is graduated in grams and has a capacity of 30 grams). B, piston rod intended to perform alternately diastole and systole in the cylinder this rod has a graduated rack and leaves the operator easy to direct the passage of the liquid, both in terms of speed and quantity. C', this valve opens from the outside to the inside of the cylinder at the moment of diastole. E' D', tube used for the arrival of blood. O', opening on the convex part of the needle for the entry of blood into its canal. C, valve opening from inside out of the cylinder at the time of the systole; O, opening on the convex part of the needle for the exit of blood out of its canal. The needles D' O' and D O have a much more pronounced curvature than in this drawing. The box containing the apparatus also contains two spare canaliculated straight needles, which are not shown here, and two canaliculated needles with their mandrel, being able to admit in their calibre the two preceding ones.

Moncoq's hematophore inaugurated too important a period in the history of instruments intended to facilitate blood transfusion for me not to give it an important place in the description of the many devices that have been imagined and used in turn.

The aim of this apparatus was to bring together, by an uninterrupted current, a plethoric subject intended to supply blood and an anaemic subject destined to receive it.

Moncoq had this device built to experiment on animals. He undertook research to make it applicable to transfusion in humans. "As early as 1863, after my various experiments in animals, I understood," says Moncoq, "that the apparatus represented (fig. 20) must be modified for transfusion in humans, the purpose of my research."

"I understood that any man would easily give a little blood to save another man, but that all danger must be removed from the generous man willing to make this sacrifice. Therefore, in order to remove all fear of phlebitis in the healthy man who would donate his blood, I had a device built, in 1863, for mediate transfusion in man; this device is just a modification of the previous device, the outlet tube and needle remain the same."

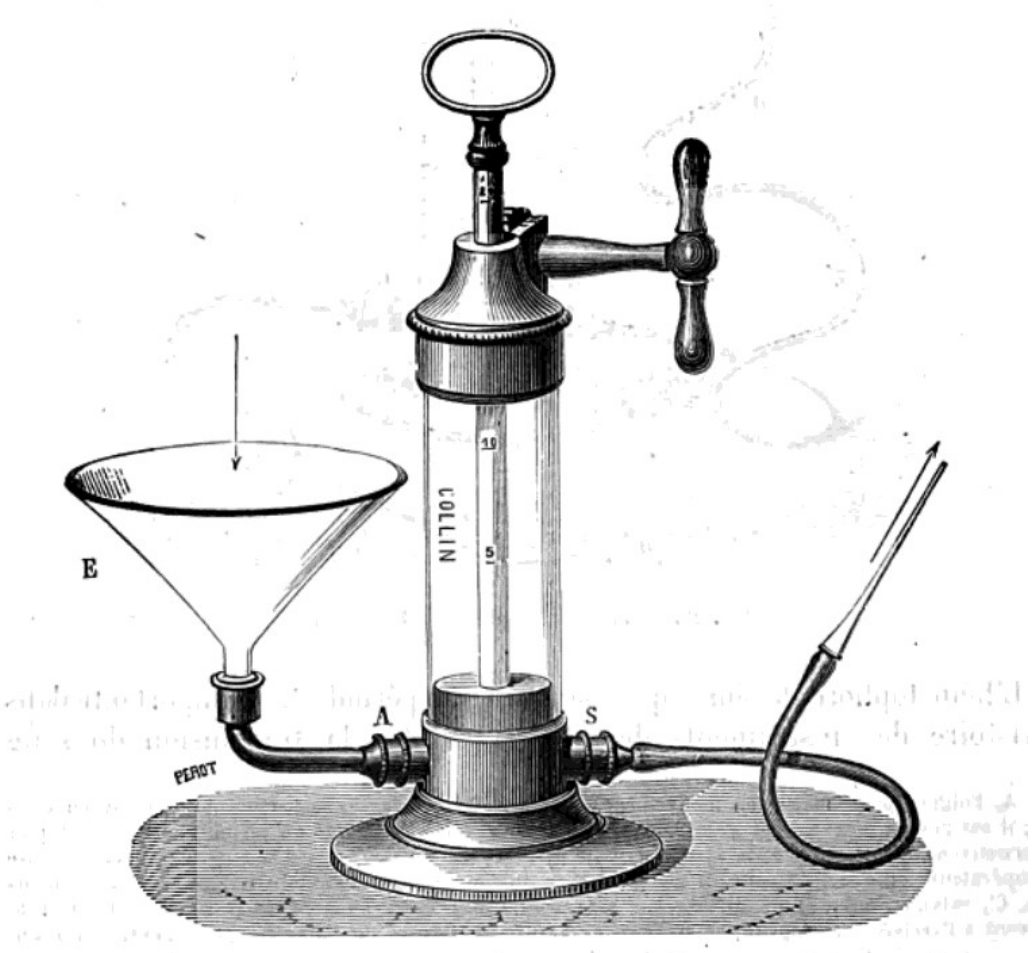

FIG. 21. – Moncoq's modified transfusion apparatus*

* E, funnel containing blood. AS, valves.

To realize this, we have only to cast our eyes on fig. 21.

In 1863, after having established this device for mediate transfusion, Moncoq thought that immediate transfusion in man was not impossible with a simple modification to the previous devices. The body of the device and the blood outlet tube remaining the same, he had an instrument fitted with a small transparent crystal cup at its lower part for the introduction of blood (fig. 22).

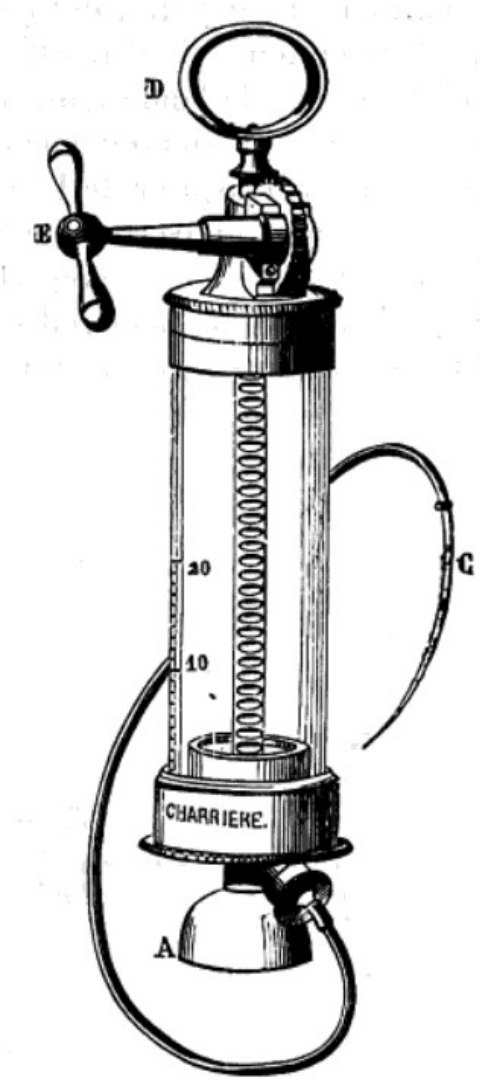

FIG. 22. – Moncoq's immediate transfusion device.*

* Modification of the previous device and allowing immediate transfusion in humans, with the maximum proximity of the two subjects. A, crystal cup which is applied to the puncture made to the subject who gives the blood and which must not press on this puncture. S, tube and needle to conduct the blood into the vein that is to receive it. The apparatus bears, like the previous one, an inlet valve placed here at the junction of the crystal cup and the transparent cylinder. It is very important here that this valve, opening from bottom to top, should be of very great mobility for the entry of the blood. There is an outlet valve opening from the inside to the outside, in the opposite direction to the previous one. (Moncoq).

We must mention Colin's ingenious device presented to the Academy of Medicine (session of 8 October 1874) by Béhier (fig. 23). The device consists of: 1° a bowl; 2° a pump body; 3° a distribution chamber; 4° a tube; 5° a trocar. The bowl has a capacity of about 300 grams of blood.

The pump body is built in conditions of exceptional simplicity. It is a regularly calibrated glass tube 8 centimetres long, equipped at its two ends with two metal armors that ensure its solidity and which are under no circumstances in contact with the blood. Its capacity is exactly 10 cubic centimetres. The piston, which is also very simple, solid, with gentle friction in the pump body, is constructed in such a way as to present the liquid blood with a perfectly regular surface. The blood is drawn from the bowl into the pump and discharged from the pump into the tube without having to come into contact of any valve. The *distribution*

chamber is formed on a cylindrical space located in the continuation of the axis of the bowl and communicating, by three equal openings, with the cuvette, with the pump, with the transfusion tube; it contains a spherical, regular, aluminium ball, the density of which has been calculated and recognised to be lower than the density of blood.

This ball floats on the blood in the chamber. At the moment of aspiration of the piston, the blood, as it descends into the pump body, displaces it, but it immediately resumes its original position; during the stride, it prevents the blood from entering the bowl; the blood can only follow the way of the transfusion tube.

This mechanism makes it impossible to propel air through the veins. It is understandable that, since the ball plays the role of a valve only on the condition that it floats, as soon as the bowl and consequently the distribution chamber, which is strictly speaking only the bottom, are empty of blood, the ball will fall of itself into the lower part and will automatically apply itself to the orifice of the transfusion tube. The pump will be able to suck in air, but it will push it back through the only way that is free, the opening of the basin. The ball which, as long as the device was loaded with blood, prevents the reflux of the blood into the bowl, as soon as the device is empty, the reflux of air into the veins.

The manoeuver consists of pulling and pushing the piston gently.

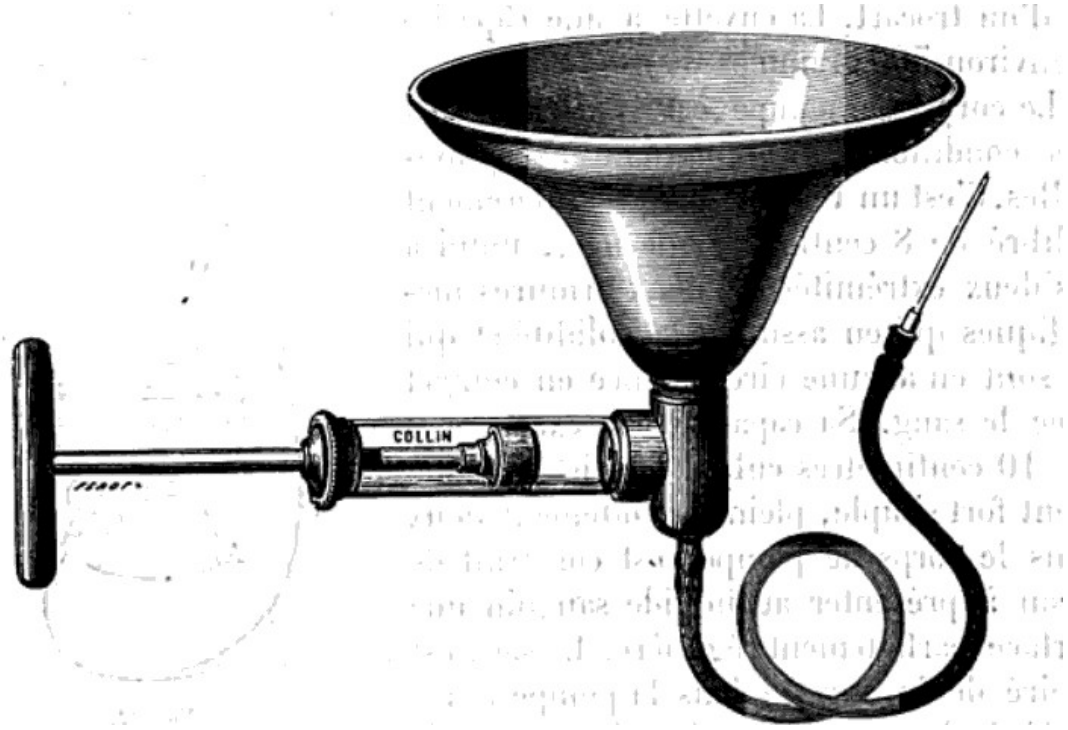

FIG. 23. – Collin's transfuser.

My transfusion devices. – First of all I used the hydrocele syringe, which is a passable instrument when operating with defibrinated blood, but which offers many disadvantages when it is done with whole blood. The most regrettable of all these disadvantages is the surgeon's obligation to handle the instrument himself, an obligation which does not leave him the freedom of his hands to monitor, maintain and immobilize the cannula in the pricked vein. Then, by operating with the syringe, it is impossible to exert a uniform pressure on the plunger, so that the arrival of blood to the heart is jerky, which is not without inconvenience, even without danger.

It is to remedy these defects that I have imagined devices whose description will demonstrate that they can be used both for immediate transfusion and for mediate transfusion.

My first device consisted of a rubber tube, at the two ends of which are two copper taps, each equipped with a valve, which can be opened and closed at will. To each tap is fitted a rubber tube, which ends in very tapered cannulas.

To complete this device I use: 1° two cannulas, crossed by three-quarters (arranged as for the three-quarter explorers): these two cannulas armed with their three-quarters are intended one to prick the vein where the blood is to be injected, the other to prick the vein which is to supply it; 2° of two mandrels.

Manner of using the instrument. – I begin by pricking the two veins between which I want to establish the blood flow with the cannulas armed with their three-quarters. Once in place, I remove the three quarters and replace with the mandrels. The latter, ending in a rounded end, is less likely to injure the walls of the vessels. This done, I remove the mandrel placed in the vein that is to supply the blood and replace it with the tapered cannula D' (fig. 24). The valves A and A' being open, I make the suction at D, I thus purge the device of the air it contains and the blood begins to flow. At this point, I put this last cannula D in place of the mandrel. The two animals are thus in contact and the blood of one passes directly into the other.

The blood passed through the apparatus too slowly; here is the modification I made to it. I placed a vacuum tube near the cannula that enters the vein of the animal I want to transfuse. It has allowed me to create a vacuum, thereby calling in the blood and accelerating its movement.

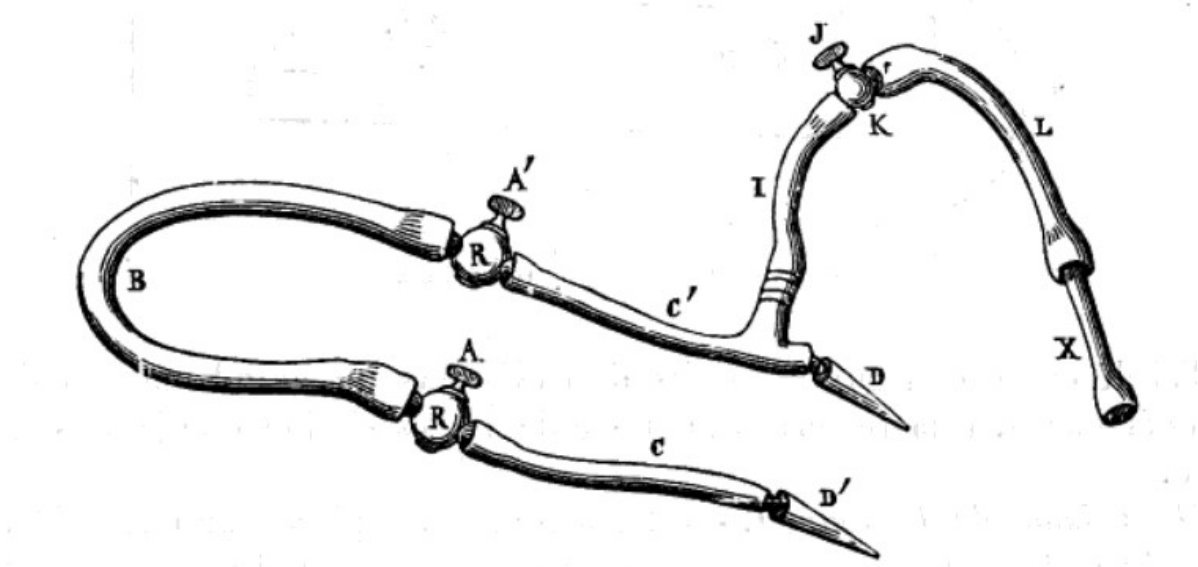

FIG. 24. – Oré's second device

As soon as I knew about Moncoq's device, I used it in all my experiments; it has, however, a defective side; it requires too many helpers. The surgeon, in fact, obliged to occupy himself exclusively with the operation of the device, is forced to entrust to a first assistant the care of keeping the cannula in the vein which receives the blood; a second is responsible for doing the bleeding. In hospitals and in civilian practice, nothing is easier than to surround oneself in this way. Is it the same in the countryside where the doctor is alone? Now, in order that the doctor placed in these exceptional conditions may not hesitate to operate, so that he may above all do so with confidence and safety, it is essential to put in his hands an apparatus which will meet the following three conditions: 1° Take charge alone and quickly the blood that must be injected into the vein; 2° Once filled, the apparatus must empty itself; this condition is essential to allow the surgeon the free use of his hands. There are in fact two capital things: 1° to maintain exactly in the vein the cannula through which the blood is to be introduced; 2° a time of no less importance is the arrival of the blood in the vessel. The blood flow must be able to be slowed down or accelerated at will; 3° It may happen that foreign bodies from outside or small quickly formed coagulums of fibrin may be

found, in spite of all the precautions taken, in spite of all the desirable dexterity, in the blood that is to be transfused. It is necessary at all costs to avoid their introduction into the circulatory torrent: these are the conditions that I have sought to achieve.

I have had to borrow a large number of their elements from the already existing devices, this will be apparent from the rest of the description I am going to give of them.

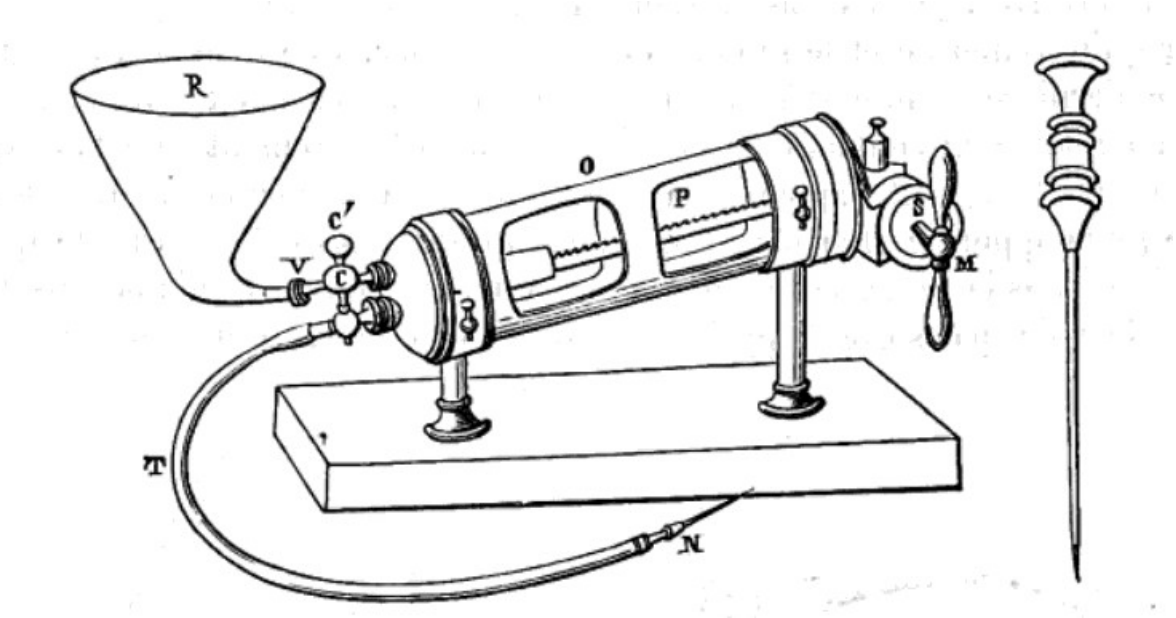

FIG. 25. – Oré's fourth device.*

* Consists of a crystal pump body P, perfectly cylindrical, with very thick walls, capable of containing 80 grams of blood (it is very rare that we are obliged to transfuse a higher dose). This pump body, inclined and fixed on two copper rods falling perpendicularly on a board where they are screwed, is crossed at its anterior part by a graduated metal rod, which allows the operator to always know the quantity of blood injected.

At the lower end of this pump casing are two conduits equipped with valves C and C'.

To one of these ducts is fitted a funnel intended to receive the blood; at the other the rubber tube terminated by the cannula which should lead it into the vein.

At the upper part of the pump body there is a pawl I intended to be placed in the gears of the piston, in order to stop it when it is judged suitable.

Next to the crank M, and crossed by its axis, is a box S containing a strong steel spring which, being in relation to the axis of the crank, has the purpose of lowering the piston, without the surgeon being obliged to intervene.

If the conduit to which the valve C is fitted is unscrewed, there will be found the fine metal trellis, which the transfused blood must pass through before arriving in the vessel, and on which it will deposit all the foreign bodies it may contain.

Mechanism of the device. – The device being placed on a table, near the patient, it is first purged of the air it contains. The valves CC' being closed (they are closed when they occupy a position perpendicular to the direction of the ducts they surmount), the vacuum is created by raising the piston to the top of the pump body: at this point, the pawl, engaging in one of the gears of the rod, immobilizes the piston.

Once the vacuum has been established, a capillary trocar surrounded by its cannula is plunged into the patient's vein, then a large bleed is made to the person who is to supply the blood, which is collected in the reservoir R; the tap C' is then opened, through which the blood rushes, *to instantly fill the pump body*. This tap is immediately closed. By a movement of lifting and rotating from right to left, the pawl is released from the gear in which it is held. If, after having articulated the rubber tube with the cannula, one comes to open the tap C, immediately the piston *descends of itself*, driving the blood into the patient's vein. The

surgeon, thus free with both hands, will secure with one the cannula placed in the vessel; with the other, according to the degree of opening given to the tap, it will slow down or accelerate the movement of the blood at will. When he wants to stop it altogether, he will only have to turn off this tap. The surgeon will therefore be able to use this instrument, whose mechanism differs from all others, to perform the transfusion alone, *without the assistance of any help.*

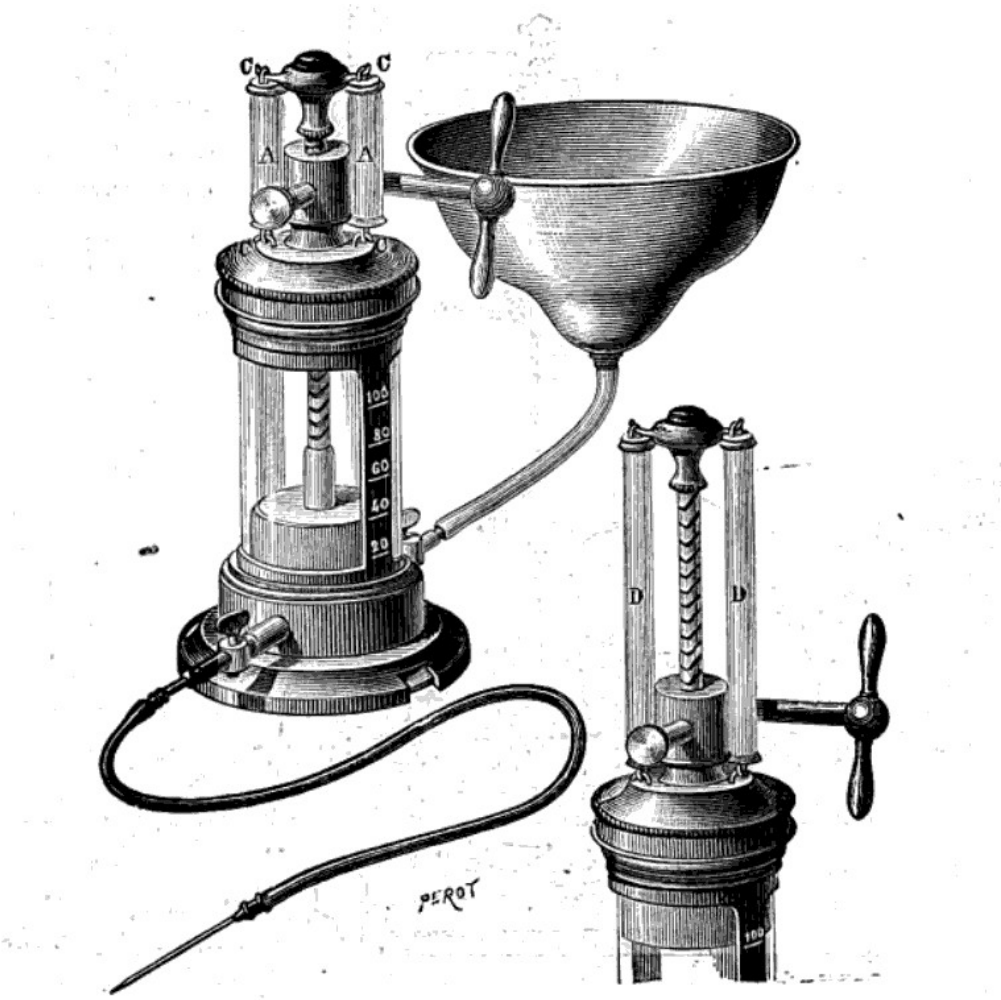

FIG. 26. – Doctor Gendron's device

Dr. Gendron's device (fig. 26) was constructed to fulfill the same indications as my device. The only difference it presents consists in the replacement of the steel spring by two strips of rubber which are tensioned by the mere fact of the elevation of the piston. The bands, by turning back on themselves, make the piston descend into the pump body; this arrangement is ingenious; the bands may have the disadvantage of breaking in consequence of too great a tension, as I have sometimes observed in my experiments on animals.

Here are the last modifications that I have made to my device, modifications which make the mechanism (fig. 27) more precise and easier:

1° The pump body, made mobile, can be straightened at will and placed in the vertical position, a more suitable arrangement for preventing the entry of air.

2° Above the outlet tap, on which a needle is fitted, I have had a graduated dial A placed in a semi-lunar shape. Each point on the dial graduation corresponds to a certain degree of the outlet opening, and, according to whether the end of the needle is placed in turn on these different points, a flow is produced by the cannula which varies in its projection force.

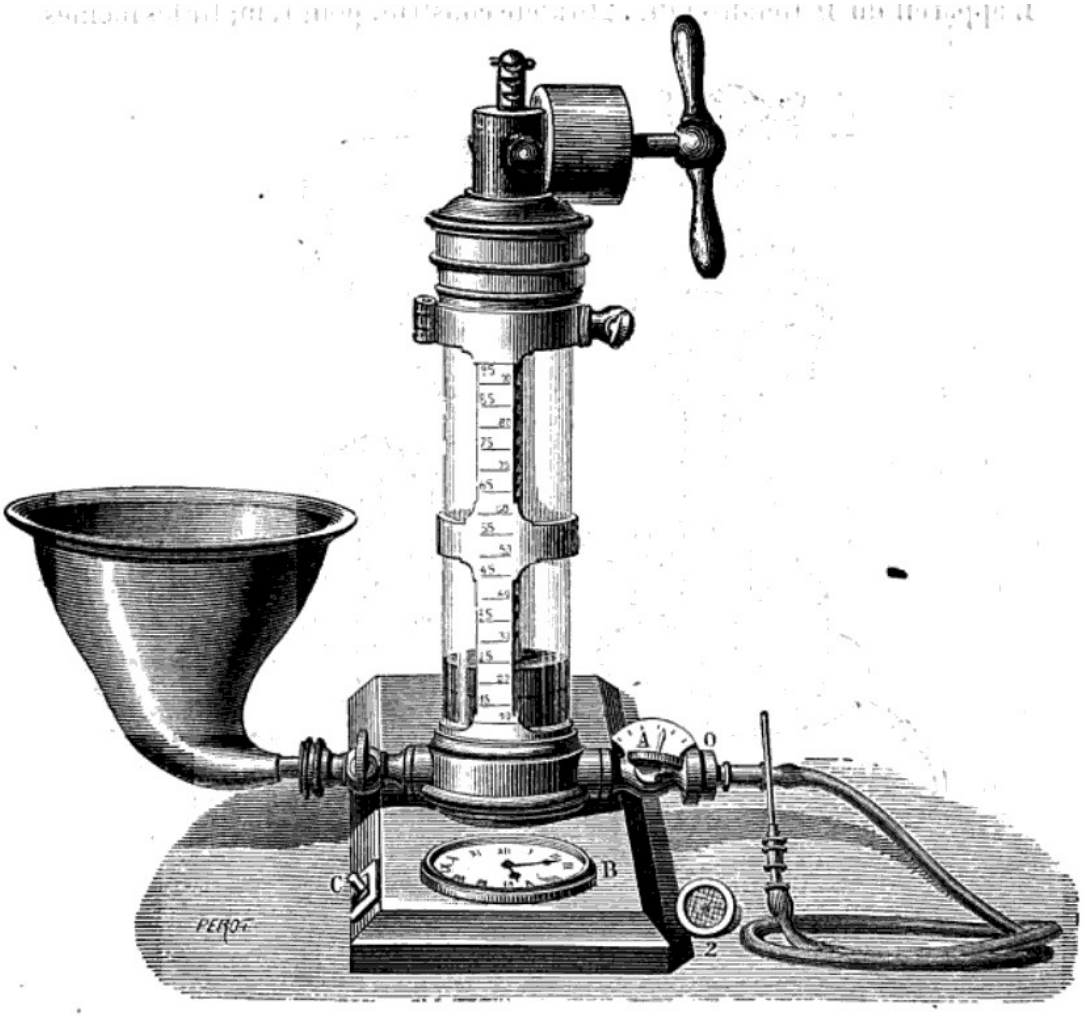

FIG. 27. – Fifth device of Oré.

Thus, the needle is placed on the first point, immediately the piston descends of its own accord into the pump body, driving out in front of it the blood which then flows *drop by drop*. If it is placed on the second division, the flow becomes a little faster. While in the first case the pump body takes four minutes to empty, it takes only *two* in the second.

With the third division, the movement is further accelerated: the pump body empties in one minute; with the fourth, in less than thirty seconds. Thanks to this arrangement, the surgeon, not having to concern himself with operating the crank of the device, since it works alone, because it alone lowers the piston as in Eguisier's irrigator; he can with one hand hold the cannula motionless in the pricked vein, while with the other he places the regulating needle on this or that point of the graduated dial, which gives it the force of flow that seems most suitable to him. Thus the transfusion is carried out by itself without difficulty, with perfect uniformity, in the flow of blood which does not offer the slightest jerk. If the patient comes to present some particular phenomena which obliges you to suspend momentarily, we have only to turn the tap A, and everything stops.

Figure 2 shows the movable metal sieve which is located at O' at the outlet opening of the device. The piece O to which the rubber tube terminated by the cannula is attached, divides with extreme ease. It follows that, if it becomes necessary during the operation to unscrew this piece because either a coagulum or some foreign body stopped by the sieve prevents the flow of blood, the manoeuver is carried out with the greatest ease, the sieve is replaced and the operation continues.

Finally, to give more precision to these researches, I had a dial B placed in front of the device. The small hand goes from one division to the next in one minute, while the large hand goes all the way around in sixty seconds.

To set this dial in motion, it is sufficient to press button G back and forth: immediately the needle starts; by pressing the same button back and forth the needle stops.

It is therefore conceivable that as soon as the crank starts to move, it will be possible, by pressing only the button G, to set the hands of the large dial in motion and to stop them when the piston has reached the bottom of the pump body. We will thus have the duration of the operation to within one second.

The vessel intended to receive the blood from the bloodletting, being screwed together, is used for the mediate transfusion. To practice immediate transfusion, I replace it with a tube similar to the outlet tube.

One more word on the operating method: In all my transfusions on humans, as in my intravenous injections, I have always punctured the vein straight away without stripping it. Stripping is a bad manoeuver that should only be resorted to when it is absolutely demonstrated that it cannot be done otherwise.

I finish by emphasizing the importance of this principle, which stems from my studies and which I do not hesitate to formulate:

"Recourse to transfusion in all haemorrhages that threaten life is a duty; to fail to do so would be more than a mistake."

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