XVI. *On the Influence of Physical and Chemical Agents upon Blood; with special reference to the mutual action of the Blood and the Respiratory Gases.*

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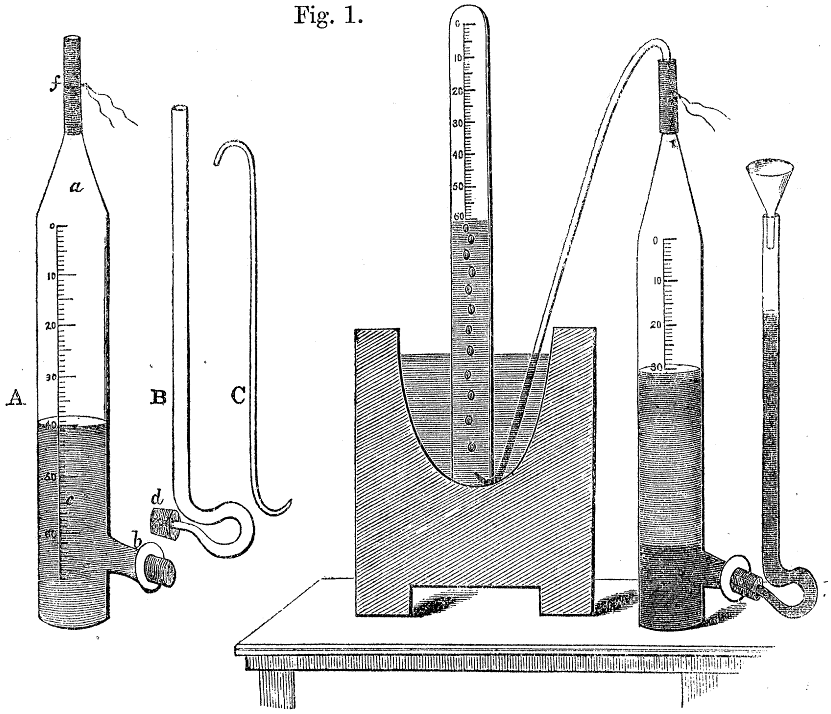
In order to prevent repetition, as well as to facilitate the understanding of the researches about to be described, it is deemed advisable at once to give a brief explanation of the manner in which the experiments were conducted. In the first place, it may be mentioned that all the gas-analyses herein detailed were made in strict accordance with the justly celebrated method of Professor Bunsen, so ably explained in his work on Gasometry. In the second place, the blood employed in the experiments was always obtained from apparently healthy animals, and with the few exceptions, presently to be alluded to, operated upon while still perfectly fresh. In the third place, the apparatus used in the majority of the experiments consisted of a graduated glass receiver of the shape represented in the accompanying figure (A), the neck of which was drawn out to

Fig. 1.



a fine capillary tube, upon the end of which was placed a piece of caoutchouc tubing.

After a certain quantity of blood (usually 62 cubic centimetres) or other fluid was introduced at the mouth (*b*), the latter was firmly closed with a tightly fitting cork, and the remaining opening (*f*) secured by a ligature, so that all communication between the external atmosphere and the gas confined with the blood was effectually interrupted.

When the experiment was completed, the gas was obtained from the receiver by plunging the lower end of the vessel into mercury, and carefully removing the cork, while it was still retained in that position, so that neither the contained gas could find an exit, nor the external air obtain admittance. A tube (B) partly filled with mercury was now carefully adjusted to the mouth of the receiver by a well-fitting cork (*d*); the receiver was next removed from the mercury trough, and a fine capillary glass tube (C) inserted into the free end of its piece of caoutchouc tubing ; the end of this tube was dipped under the surface of mercury and the ligature at *f* removed. The mercury in B immediately descended and forced the atmospheric air out of the tube C, which in its turn became filled with gas from the receiver. The end of the tube C was then brought under an inverted eudiometer filled with mercury, and more of that liquid poured into B until sufficient gas was obtained from the receiver for analysis. In the fourth place, the temperature of the human body was imitated by employing an artificial digesting apparatus which could be readily kept at a constant heat of 38° C.

Lastly, the experiments were performed in a gas-laboratory, the temperature of which varied but slightly during the twenty-four hours, and their performance was thereby greatly facilitated. For the use of this laboratory I am deeply indebted to the President and Council of University College, London, who most liberally placed it at my entire disposal during a period of three years.

As indicated by the title of the paper, the series of researches about to be detailed is devoted to the influence of some physical and chemical agents on the blood with reference to its action on the respiratory gases. For the sake of convenience, the communication is divided into two parts.

The first includes the influence of the following physical agents.

a. The effect of simple diffusion in producing a change in the mixture of gases confined with blood.

b. The influence of motion on the changes reciprocally exerted upon each other by blood and atmospheric air.

c. The influence of time on the interchange of the respiratory gases.

d. The effect of temperature on the same, from 0° C. to 38° C.

e. The influence of the age of the blood, including the effect of the putrefaction.

The second part of the communication is devoted to the consideration of the influence of chemical agents, especially such as are usually denominated powerful poisons. These agents are selected from the three kingdoms.

a. Animal.

b. Vegetable, and

c. Mineral.

In relating the experiments, I have sedulously avoided advancing any theories with regard to the mode of action of any of the agents studied, and on one or two occasions only has even as much as a hint been given that the results obtained might in any way tend to the elucidation of the action of remedies or the mode of death by poison. The reticence in this instance has arisen from the circumstance that several of the results are so novel and at the same time so pregnant with material for theorizing, that the individual facts might soon be lost sight of in a sea of speculation. It appears to me therefore that the ends of science will be much better served if I confine myself to a description of the bare data, rather than propound the numerous theories which the different results suggest, and which, although they might make the paper more interesting, could not in reality add to its true value.

I may also mention that the material is so arranged as to be easily accessible, each fact having been made as far as possible independent of its associates, in order that future inquirers may find no difficulty in isolating any particular result they may desire specially to investigate. Moreover, the progressive details of each experiment are given in the form of an appendix, so that the initiated investigator can follow it with facility through its different stages, either for the purposes of comparison or verification *.

Part I.—INFLUENCE OF PHYSICAL AGENTS.

(a) *The effect of Diffusion in modifying the composition of atmospheric air confined with fresh blood.*

The influence of both venous and arterial blood was studied.

1st. As regards arterial blood.

A certain quantity of arterial blood was allowed to flow directly from the femoral artery of a healthy dog into a glass receiver, and after being carefully secured along with 100 per cent. of atmospheric air, was placed aside in a warm room during forty-eight hours. At the end of this time the receiver was opened in the manner already described, and a certain quantity of its gas removed for analysis.

* The Appendix is deposited for reference in the Archives of the Royal Society. The first analysis only is given in detail as a specimen.

No. 1.—Air from arterial blood of Dog.

	Volume.	Barometric pressure.	Temperature.	Vol. at 0° C. and 1 metre pressure.
For carbonic acid.				
Air employed	140·3	718·7	7·7	98·08
After absorption of carbonic acid	139·0	719·4	5·8	97·91
For oxygen.				
Air employed	244·2	359·0	6·2	85·72
After addition of hydrogen	331·8	449·9	6·1	146·00
After explosion	258·0	372·9	4·5	94·64

No. 1.—In 100 parts of air.

Oxygen	19·928	Total oxygen 20·111
Carbonic acid	0·183	
Nitrogen	79·889	

2nd. As regards venous blood.

A certain quantity of venous blood was allowed to flow directly from the jugular vein of an apparently healthy dog into a glass receiver. It was then secured along with 100 per cent. of atmospheric air, and kept, as in the previous case, in a room of moderate temperature during forty-eight hours. The gas from this blood gave the following result:—

No. 2.—In 100 parts of air.

Oxygen	18·400	Total oxygen 20·557
Carbonic acid	2·157	
Nitrogen	79·443	

As the composition of ordinary atmospheric air is supposed to be:—

In 100 parts.

Oxygen	20·960	Total oxygen 20·962
Carbonic acid	0·002	
Nitrogen	79·038	

it appears from the results of these experiments that both arterial and venous blood act in precisely the same manner, the amount alone of their action being different. As might have been expected, the venous blood has yielded by simple diffusion a much greater amount of carbonic acid than the arterial blood. Moreover, under the same circumstances it has absorbed a much larger quantity of oxygen.

In 100 parts.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
Atmospheric air operated upon............	20·960	0·002	79·038	20·962
Air after forty-eight hours' contact with—				
Arterial blood	19·928	0·183	79·889	20·111
Venous blood	18·400	2·157	79·443	20·557

The total amount of oxygen is in both cases slightly diminished, and with this diminution the proportion of nitrogen, which is calculated by "difference," is necessarily increased.

(b) *Effect of Motion on the action of blood on atmospheric air.*

The mere effect of motion was attempted to be ascertained in the following manner. Two portions of the same blood of a calf, after being thoroughly arterialized by being repeatedly shaken with renewed portions of air, were confined in receivers with 100 per cent. of air, and treated in a precisely similar manner during forty-eight hours, except that one blood had a small quantity of quicksilver added to it in order to render its agitation more complete. The following were the results obtained.

Pure blood of calf, forty-eight hours' action with 100 per cent. of atmospheric air:—

No. 3.—In 100 parts of air.

Oxygen . . .	15·14	Total oxygen 18·22
Carbonic acid . .	3·08	
Nitrogen . . .	81·78	

Same blood shaken with quicksilver, forty-eight hours' action with 100 per cent of air, yielded the following result:—

No. 4.—In 100 parts of air.

Oxygen	4·11	Total oxygen 11·64
Carbonic acid . .	7·53	
Nitrogen . . .	88·76	

	Oxygen.	Carbonic acid.	Nitrogen.
Ox-blood	15·14	3·08	81·78
Ox-blood plus quicksilver...	4·1	7·53	88·76

The difference between these results is very striking, so much so, that it was thought advisable to discover if the mercury had not exerted some undefined chemical action, either on the air or blood, in addition to its mere mechanical influence in facilitating their thorough mixing. With the view of solving this question, other two portions of blood were taken, and while to one a small quantity of quicksilver was added, the other had an equal amount of powdered glass mixed with it. Both receivers were put aside in a place where the temperature never exceeded 7° C. At the end of five days, during which period they were repeatedly shaken, the air was analyzed for carbonic acid.

No. 5.—In 100 parts of air.

Carbonic acid from blood, plus quicksilver . .	1·72
,, ,, ,, ,, ,, glass . . .	1·30

As it appeared from this and the foregoing that the action of the mercury was something more than merely mechanical, in order to ascertain the influence of motion alone, two equal portions of the same fresh venous blood from an ox were placed in receivers with similar proportions of atmospheric air (1 vol. of blood to 3 vols. air) and kept at a temperature of 30° C. during six hours. In each receiver was placed a small quantity of powdered glass, in order the more effectually, when the receivers were shaken, to mix the blood. The first receiver was shaken only three minutes at a time, the second five. In all other respects they were treated exactly alike*.

Air after being enclosed during six hours at a temperature of 30° with venous blood shaken with glass, three minutes at a time. Result:—

No. 6.—In 100 parts of air.

Oxygen	14·78	Total oxygen 18·20
Carbonic acid . .	3·42	
Nitrogen . . .	81·80	

Same blood as the preceding, under precisely the same circumstances, but shaken during five minutes at a time. Result:—

No. 7.—In 100 parts of air.

Oxygen	14·49	Total oxygen 18·93
Carbonic acid . .	4·44	
Nitrogen . . .	81·07	

It thus appears that the mere effect of motion has an influence on the amount of gases interchanged.

(c) *Influence of Time on the interchange of gases between the blood and air.*

It was found from a series of experiments (as might have been expected from our knowledge of the respiratory process) that the longer air is retained in contact with blood, the greater is the change worked in its chemical composition. Thus it was found

* It may be here mentioned that during the course of these experiments it was found necessary, in order to arrive at anything like correct results, not only to use (in the comparative experiments) the blood of the same species of animal, but of the same bleeding; as for some cause or other, the state of the digestion or the health of the animal, different bleedings invariably gave slight differences in result.

that if the ordinary respiratory act was imitated as closely as possible, by simply passing a current of pure atmospheric air through a series of twenty-four blown glass bulbs, partly filled with defibrinated arterialized ox-blood, kept in a digestive apparatus so constructed as to be capable of being retained at the temperature of the human body, the air underwent the following change.

Air after passing through twenty-four bulbs half filled with blood, at a temperature of 38° C., gave the following results:—

No. 8.—In 100 parts of air.

Oxygen	20·61	Total oxygen 21·57
Carbonic acid . .	0·96	
Nitrogen . . .	78·43	

It is thus seen that the blood out of the body exerts a similar chemical action upon air brought in contact with it as it does in the lungs of the living animal, at least so far as the interchange of gases is concerned. The next point being to retain the air longer in contact with the blood at the same temperature, the following experiment was performed.

Defibrinated fresh ox-blood, after being well arterialized by shaking it with renewed portions of air, was kept during $1\frac{1}{2}$ hour in contact with 100 per cent. of pure atmospheric air at a temperature of 38° C.

No. 9.—In 100 parts of air.

Oxygen	19·76	Total oxygen 22·68
Carbonic acid . .	2·92	
Nitrogen . . .	77·32	

Another portion of the same blood as the preceding was heated in precisely the same manner, but instead of being kept only $1\frac{1}{2}$ hour in contact with the air it was retained $3\frac{1}{4}$ hours.

No. 10.—In 100 parts of air.

Oxygen	18·80	Total oxygen 22·87
Carbonic acid . .	4·07	
Nitrogen . . .	77·13	

The effect of time is well illustrated in these three examples, for with the single exception of the period during which the air was in contact with the blood, all the other factors were identical. By placing the results in a tabular form, the influence of time is more easily appreciated.

	Oxygen.	Carbonic acid.	Nitrogen.
Air employed	20·96	00·00	79·04
After a few seconds' action by blood	20·61	00·96	78·57
After $1\frac{1}{2}$ hour's action	19·76	02·92	77·32
After $3\frac{1}{4}$ hours' action	18·80	04·28	76·92

It is here seen that the reciprocal action of blood and air is gradual, and one requiring time, a fact which supports the view that the inspired air gradually combines with the constituents of the blood in the torrent of the circulation.

(d) *Influence of Temperature.*

1st. As regards the amount of carbonic acid exhaled.

Three equal portions of freshly-defibrinated ox-blood, after being well arterialized by repeated agitation, were put into receivers with 100 per cent. of air, and kept at the following different temperatures during $3\frac{1}{4}$ hours:—

1st. At 0° C.
2nd. At 26° C.
3rd. At 38° C.

No. 11.—The results when calculated yield in 100 parts of air,—

1st.	Temperature	0° C.=0·00	carbonic acid.
2nd.	„	26° C.=3·08	„
3rd.	„	38° C.=4·07	„

Thus the higher the temperature, up to a certain point, the greater is the amount of carbonic acid exhaled.

In order to see if the same rule is applicable to the oxidation of the constituents of the blood, other three portions of defibrinated ox-blood were taken, and after being treated in the usual way, were kept at different temperatures during twenty-four hours.

(*a*) In an ice cellar.
(*b*) In a room at 12° C.
(*c*) In an artificial digesting apparatus heated to 38° C.

(*a*) Ox-blood with 100 per cent. of air, twenty-four hours' action at 0° C. Result:—

No. 12.—In 100 parts of air.

Oxygen	17·43	Total oxygen 18·02
Carbonic acid	0·59	
Nitrogen	81·98	

This experiment was made in foggy weather.

(*b*) Ox-blood with 100 per cent. of air, twenty-four hours' action at 12° C. Result:—

No. 13.—In 100 parts of air.

Oxygen	12·54	Total oxygen 15·31
Carbonic acid	2·77	
Nitrogen	74·69	

(*c*) Ox-blood with 100 per cent. of air, twenty-four hours' action at 38° C. Result:—

No. 14.—In 100 parts of air.

Oxygen	00·00	Total oxygen 22·40
Carbonic acid . .	22·40	
Nitrogen . . .	77·60	

The amount of carbonic acid exhaled in this case seems very extraordinary, nevertheless I believe that it is perfectly correct, for another portion of the same blood, used as a controlling experiment, yielded to within a fraction of the same amount of carbonic acid. The fraction of difference, too, was an excess, being 22·6 instead of 22·4. Thus 24 hours at 38° C. Result:—

No. 15.—In 100 parts of air.

Carbonic acid=22·6.

As the weather was exceedingly foggy at the time these experiments were made, it was deemed advisable to analyze the fog in order to ascertain how much carbonic acid it contained, lest the extraordinary results obtained in the last two experiments might be due to that cause, or to some disease in the blood.

No. 16.—Result of an analysis of fog in 100 parts of air.

Carbonic acid=0·52.

This is the greatest amount of carbonic acid I ever obtained from London fog, and large though it be, it is still far too small a quantity to account for the results in the last two cases.

By placing the different effects of temperature in a tabular form, the influence exerted by that factor over the chemical changes occurring in blood will be still better appreciated.

Defibrinated ox-blood.	Oxygen.	Carbonic acid.	Nitrogen.
Temperature 0° C. 24 hours	17·43	00·59	81·98
" 12° C. "	12·54	02·77	74·69
" 38° C. "	00·00	22·40	77·60

The influence of temperature on the interchange of gases is equally well illustrated by comparing the results of experiment 13 with that of experiment 10, when it will be seen that 3¼ hours' action at a temperature of 38° C. (the temperature of the animal body) yields much more carbonic acid than 24 hours' action at a temperature of 12° C.

100 per cent. of air with ox-blood.	Oxygen.	Carbonic acid.	Nitrogen.
24 hours' action at 12° C.....................	12·54	2·77	74·69
3¼ " " 38° C.....................	18·80	4·07	77·13

The effect of temperature on the individual constituents of the blood was also studied, but only with red coagulum was it found sufficiently well marked to merit being noticed here. Three equal portions of coagulum from fresh ox-blood were confined with 100 per cent. of atmospheric air during six hours at the following temperatures.

(*a*) At 21° C.; (*b*) at 30° C.; (*c*) at 36° C., with the following results:—

Amount of carbonic acid in 100 parts of air in

No. 17. (*a*)	6 hours at	temperature of	21° C.=2·34	carbonic acid.
No. 18. (*b*)	,,	,,	30° C.=5·18	,,
No. 19. (*c*)	,,	,,	36° C.=7·29	,,

It is thus seen that the amount of carbonic acid exhaled by red-blood coagulum increases with the temperature as far as the experiment went, namely from 21° to 36° C.

2nd. As regards the influence of cold in retarding the reciprocal chemical changes which occur between atmospheric air and blood, a striking proof of which is to be found in the result of the following experiment.

Two ounces of arterial blood were allowed to flow directly from the carotid artery of a dog into a glass receiver, which in order still further to ensure its being thoroughly oxidized, as well as to prevent its coagulating into a solid mass, was shaken with renewed portions of air during two hours; a small quantity of fluid mercury being also employed to prevent the coagulation. After this treatment the receiver was firmly corked and kept (with occasional agitation) in a room the temperature of which never exceeded 7° C. during five whole days.

Dog's arterial blood five days at a temperature under 7° C.* Result:

No. 20.—In 100 parts of air.

Oxygen	12·62	Total oxygen 14·34
Carbonic acid . .	1·72	
Nitrogen . . .	85·66	

On its removal from the receiver, the blood, although dark in colour, had a perfectly fresh odour. The diminished temperature not only retarded the chemical changes, which for the sake of convenience we may term "respiratory," but also those decompositions and transformations so intimately connected with oxidation, to which the name "putrefaction" has been given.

(e) *Influence of the age of the blood.*

The putrefactive changes occurring in blood are exceedingly curious, and perhaps it may not be out of place if some of them be here alluded to.

The following series of experiments were made on sheep's blood. The first began within two hours after the blood was withdrawn from the animal, the last after it had stood 688 hours.

* The first part of this experiment has been already given, but it is here again repeated in order to save the time of the reader in referring back to it, and so it is occasionally done with some others.

Two ounces of well defibrinated sheep's blood, after being arterialized by constant agitation with renewed portions of air during twenty minutes, were put into a receiver with 100 per cent. of atmospheric air and kept during twenty-four hours in a room the temperature of which varied from 6° to 12° C. Result:—

No. 21.—In 100 parts of air.

Oxygen	13·76	Total oxygen 15·81
Carbonic acid	2·05	
Nitrogen	84·19	

A similar portion of the same blood as the preceding, after being exposed to the air in an open glass vessel during sixty hours, was treated in an exactly similar manner, and then placed in a receiver with 100 per cent. of air. The temperature of the room during the time of the experiment varied, as before, from 6° to 12° C. The blood after the sixty hours' exposure had become of a dark venous hue, but it still arterialized readily on being agitated with fresh portions of air. It smelt slightly, as if putrefaction had begun. Under the microscope the red blood-corpuscles were perfectly distinct. Result:—

No. 22.—In 100 parts of air.

Oxygen	2·88	Total oxygen 6·57
Carbonic acid	3·69	
Nitrogen	93·43	

This blood, which was of a bright arterial hue when put into the receiver with the air, at the end of the twenty-four hours had again resumed the venous colour. On shaking the vessel the blood looked as if it were decomposed. It remained of a dark purple colour on the sides of the glass, although the blood was at this time eighty-four hours old. On removing it from the receiver, and shaking it with renewed portions of atmospheric air, it again assumed the arterial tint. After the sheep's blood was 136 hours old it was of a dark purple colour, and when a thin layer was spread over a white plate it looked quite granular. When examined with the microscope, the blood-corpuscles were still found perfectly distinct in their outline, and on being measured they averaged $\frac{1}{400}$ millim. ($\frac{1}{10,000}$ inch) in diameter. The blood arterialized readily on being shaken with fresh air.

A third portion of this blood was taken and subjected in every respect to precisely the same treatment as in the two preceding cases. Result:—

No. 23.—In 100 parts of air.

Oxygen	1·01	Total oxygen 5·32
Carbonic acid	4·31	
Nitrogen	94·68	

A fourth portion from the same blood, after it was 184 hours old, still became of an arterial hue when well shaken with air, although it had a film of fungi on its surface, and smelt strongly as if it were putrid. When once arterialized it looked exactly like freshly-drawn blood, and when examined microscopically it showed the red blood-corpuscles as well as if it had only been a day old. Indeed, by its previous history, and smell alone, could a stranger have had any idea of its having been drawn from the animal more than a few hours. The fourth portion was treated in a similar manner, and for the same length of time as the others.

In this case, for some cause or other, no explosion could be obtained, even after the addition of 50 per cent. of explosive gas. Result:—

No. 24.—In 100 parts of air.

Oxygen	0·00
Carbonic acid . .	4·91
Nitrogen . . .	95·09

The blood after 304 hours' exposure still arterialized when well agitated with air. On using the microscope, the corpuscles were found to be distinct, though not so numerous as at first. They were best seen without adding water. Indeed the addition of water almost totally destroyed them by instantly dissolving their attenuated walls and allowing their contents to escape.

A fifth portion of this blood was treated precisely as the preceding examples with 100 per cent. of air in one of the usual glass receivers, the temperature of the room varying, as before, from 6° to 12° C.

The oxygen, if there was any, was not estimated.

No. 25.—In 100 parts of air.

Carbonic acid . . 4·99

The blood after being kept 688 hours still arterialized on being thoroughly shaken with renewed portions of air. It was fearfully fetid, and contained numbers of living animalcules of the Vibrio class. The red corpuscles were still distinct, though in greatly diminished quantity, from numbers of them having become broken up and dissolved*.

The usual quantity of this blood was put into the receiver with 100 per cent. of air and treated during twenty-four hours in the ordinary manner.

No. 26.—In 100 parts of air†.

Carbonic acid . . 5·11

* This series of experiments was performed in the winter months, but in one conducted during the months of April, May, June, and July, I was able to detect blood-corpuscles in the putrid fluid after it was three months and seven days old; so that blood-corpuscles appear to be much more persistent bodies than is in general imagined.

† The oxygen was also estimated in this case, but unfortunately without a controlling experiment being at the same time performed, so it is of little value. The following is the result of the analysis.

No. 27.—In 100 parts of air.

Oxygen . . 2·10

The analysis of the gas after twenty-four hours' contact with the blood therefore stands thus:

In 100 parts of air.

Oxygen	2·10	Total oxygen 7·21
Carbonic acid . .	5·11	
Nitrogen . . .	92·79	

As it is rather troublesome to carry the results of these analyses in the mind, I shall now give them in a tabular form, when it will be at once evident to any one who has given attention to the subject, that the chemical changes exerted upon air by putrefaction, in so far as they are here studied, are very different from the true respiratory ones previously alluded to.

In 100 parts of air.	Oxygen.	Carbonic acid.	Nitrogen.
1st portion of fresh blood	13·76	2·05	84·19
2nd „ same „ 60 hours old	2·88	3·69	93·43
3rd „ „ „ 136 „	1·01	4·31	94·68
4th „ „ „ 184 „	0·00	4·91	95·09
5th „ „ „ 304 „	——	4·99	——
6th „ „ „ 688 „	——	5·11	——

It is here seen that the process of putrefaction exerts, up to a certain extent, the same effect on the absorption of oxygen and exhalation of carbonic acid by the constituents of the blood, as was observed to be exercised by an increase of temperature. Thus we find that the older the blood becomes the more oxygen it extracts from the air, and the more carbonic acid does it at the same time yield. Here, however, the analogy stops. For we find that while in those cases where the normal respiratory action is such as to have produced the exhalation of more than 5 per cent. of carbonic acid, the oxygen does not entirely disappear from the air (see experiments 35 and 58, Part II.), and in those again where the oxygen has been entirely taken up by the blood it is again all returned to the atmosphere, as seen in the results of experiment 14 related at page 695. During the putrefactive process, on the other hand, the amount of oxygen absorbed is exceedingly great in proportion to the quantity of carbonic acid exhaled.

Part II.—INFLUENCE OF CHEMICAL AGENTS ON THE BLOOD.

Effect of Animal Products.

Snake Poison.

For the purpose of studying the effect of animal poisons upon the reciprocal action of blood and atmospheric air, I obtained, through the kindness of the late Mr. Mitchell, Secretary to the Zoological Gardens, the loan of two African Puff Adders. They were 3 feet in length, and about 8 inches in circumference at the thickest part.

The physiological action of animal poisons being as yet imperfectly understood, before alluding to the special action of the poison on the blood, I shall briefly relate the history of one of the experiments.

The experiments were performed at University College, in the presence of my colleagues, Professors SHARPEY, ELLIS, and WILLIAMSON. The serpents had eaten nothing during eight days, so it was supposed that their poison-bags were well charged with venom.

A large dog was bitten by one of the snakes over the right eye. The immediate appearance of a drop of blood indicated the position of the wound. In three minutes the dog became very restless, and gave a low whine as if in pain. After moving about the room for ten minutes searching for a comfortable place to lie down on, he placed himself in the coolest part of the chamber, and laid his head on the cold stones, as if to relieve headache. He moaned as if in distress. In a quarter of an hour after he received his wound the pulse had fallen from 100 to 64 per minute. As the effects of the poison passed away the pulse gradually recovered, and in twenty-five minutes it was again as high as 96 per minute.

In one hour after being bitten the dog had so far got over the effects of the poison as to be able to run about.

The serpent was once more allowed to bite him. The same train of symptoms again appeared, but in a more intense degree, and within twenty-five minutes he had become insensible. He looked as if in a profound sleep, from which he could not be roused. The respirations were 40 per minute, and the pulse so feeble in the femoral artery that it was found impossible to count it. The pupils were dilated.

Half an hour after being bitten the second time convulsive twitchings began to appear in the fore limbs and in the muscles of the neck. In ten minutes more the whole body became convulsed. The limbs were stretched out, and the head jerked backwards. During the convulsions the respirations rose to 90 per minute; but they subsided to 40 in the intervals. The temperature of the rectum gradually fell in the course of one hour and a half from 38° to 35° C. In two hours the respirations were reduced to 9 per minute, the animal temperature at the same time being 34° C. The pulse was completely imperceptible; even the heart's action could not be felt through the ribs.

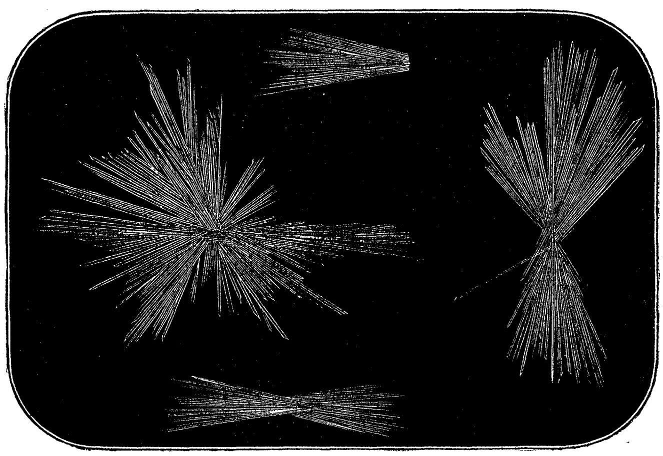
In two hours and a quarter the animal appeared to be dead; but on making an incision into the thorax he gave a gasp. After waiting some time, without observing any further sign of life, another incision was made, when he again gasped, but only once. On opening the thorax the heart was found pulsating at the rate of 60 per minute; it was, however, more like a quivering than a true pulsation. The tissues of this and of the other animals killed by the puff adders presented a very strange appearance, namely, numerous extravasations of blood throughout the body, some small, some large. For example, in this animal there was an extravasation of blood into the anterior mediastinum, and into the tissue of the pericardium, but no effusion into the pericardium itself. There were extravasations along all the great veins, into the cellular tissue of the pancreas, throughout the diaphragm, beneath the peritoneum, and all over the abdomen. The interior of the latter, indeed, looked exactly as if it had been sprinkled over with blood. A similar condition also existed in the subcutaneous cellular tissue. In fact, had the history of the case not been known, it would have been supposed that the animal had laboured under a severe form of purpura hæmorrhagica.

In the neighbourhood of the wounds there was great swelling, as well as an extravasation of brownish putrid looking blood. Everything pointed to blood poisoning.

The state of the spleen merits special attention. It was of a dark bluish olive tint; quite peculiar. I have never met with a similar hue in any other case of poisoning. On exposure to the air the blood became arterialized, and the organ then lost the strange appearance. The muscles were darker than usual. In the course of a few hours they passed into a state of rigor mortis, which was quite distinct seventeen hours after death. The brain was very anæmic, and showed no signs of extravasation.

In the course of a few weeks after this experiment was made three of the puff adders died and were sent to me for examination. They were in exceedingly good condition, and beyond having fatty livers there was no apparent disease. On removing the poison from their poison bags and allowing it slowly to evaporate on a glass slide, beautiful crystals were observed to form in it similar to the specimens represented in the accompanying figure.

Fig. 2.



Crystals from puff-adder poison.

This crystalline body seems to be peculiar to this species of snake, as I failed to obtain it from the common adder, as well as from two specimens of Cobra, one from Morocco, and one from Egypt.

Examination of the Blood.

Under the microscope, the red corpuscles were in general normal in appearance. There were, however, a number of three-cornered ones to be seen, like what is sometimes met with in the half-putrid blood of fish. There was also an excess of white corpuscles, which might have been due to the animal being in full digestion.

After the blood had stood for some hours in a glass vessel, although not coagulated, it had deposited the corpuscles and left a layer of serum on the top*. Shaken with air it arterialized readily. It contained 0·235 gramme (3·64 grains) of urea per ounce. No sugar could be detected in it, yet after standing a couple of days it became quite acid. A quantity of this blood, after being thoroughly arterialized, was put into a receiver with 100 per cent. of air, and in order to make the experiment as exact as possible, a healthy dog was sacrificed, and a similar quantity of its blood treated in exactly the same manner. As this experiment was performed during the season of the year when the days were short, and I could not work in the laboratory after four o'clock, I carried the receivers home with me, and repeatedly agitated them during the evening, and pretty far on into the night.

After twenty-four hours' action the analyses of the gases gave the following results:—

1st. Blood of healthy dog. Result:—

No. 28.—In 100 parts of air.

Oxygen . . .	19·700	Total oxygen 20·109
Carbonic acid .	0·409	
Nitrogen . . .	79·891	

2nd. Blood of dog poisoned by puff adder. Result:—

No. 29.—In 100 parts of air.

Oxygen . . .	17·09	Total oxygen 18·18
Carbonic acid .	1·09	
Nitrogen . . .	81·82	

It is here observed that there has been a marked difference in the action of the two bloods. The puff-adder poison seems to have accelerated the transformations and decompositions upon which the absorption of oxygen and the exhalation of carbonic acid by the blood depend. By placing the results in the form of a Table, this fact is rendered still more apparent.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of atmospheric air	20·960	0·002	79·038	20·962
Ditto, after being acted on by pure blood	19·700	0·409	79·891	20·109
Ditto, after being acted on by poisoned blood..	17·09	1·09	81·82	18·18

* On opening the other animals some hours after death the blood was found to be fluid, but it coagulated after its withdrawal from the body. It formed a jelly rather than a clot. There seemed to be a marked diminution in the amount of fibrin, as well as a thinning of the blood, in all the cases.

As these results are probably different from what most persons may have expected, it may be advisable briefly to relate the controlling experiments, at least so much of them as refer to the exhalation of carbonic acid. They were performed in a precisely similar manner, except that the proportion of blood to that of air was as one to three.

1st. Healthy dog. 1 volume of pure blood to 3 volumes of air. Twenty-four hours' action at temperature under 12° C. Result:—

No. 30.—In 100 parts of air.

Carbonic acid	0·38

2nd. Blood of dog poisoned by puff adder. 1 volume of blood to 3 volumes of air. Twenty-four hours' action at temperature under 12° C. Result:—

No. 31.—In 100 parts of air.

Carbonic acid	0·78

Here too it is seen that, although treated in every respect alike, the blood of the poisoned dog exhaled more carbonic acid than that of the healthy animal.

Uric Acid.

As uric acid, although a normal constituent of the animal body, may be regarded in the light of an animal poison, inasmuch as it is an effete product, it was experimented with in the following manner.

Two portions of well defibrinated sheep-blood, after being thoroughly arterialized, were placed in receivers with 100 per cent. of atmospheric air. To one of them was added 0·2 gramme (3·1 grains) of pure uric acid prepared from human urine (the uric acid was thoroughly pounded in distilled water and then mixed with the blood in a mortar; 62 grammes of blood was the quantity employed). The pure blood was treated in the same way, but with distilled water alone. After twenty-four hours' action under identical circumstances, the air of the receivers was analyzed.

Air after being in contact with pure blood of sheep during twenty-four hours. Result:—

No. 32.—In 100 parts of air.

Oxygen . . .	13·90	Total oxygen 15·85
Carbonic acid .	1·95	
Nitrogen . . .	84·15	

Air after being in contact with sheep's blood to which uric acid was added. Result:—

No. 33.—In 100 parts of air.

Oxygen . . .	13·17	Total oxygen 15·79
Carbonic acid .	2·62	
Nitrogen . . .	84·21	

It is thus seen that the presence of an abnormal amount of uric acid in blood hastens the chemical decompositions and transformations upon which the absorption of oxygen and exhalation of carbonic acid depend.

Animal Sugar.

As an illustration of the action of animal sugar upon blood, the following experiment may be cited. To a third portion (62 grammes) of the same blood as was used in the two preceding experiments, 0·4 gramme (6·2 grains) of sugar obtained from the urine of a diabetic patient were added. The sugar was first made into a syrup with a small quantity of distilled water, and then mixed in a mortar with the blood. In order to avoid all possibility of error, the pure blood, as before stated, was treated in the same way with distilled water alone. Result:—

No. 34.—In 100 parts of air.

Oxygen . . .	15·01	Total oxygen 16·62
Carbonic acid .	1·61	
Nitrogen . . .	83·38	

It is here seen that the animal sugar had the effect of retarding the respiratory changes produced in atmospheric air by blood, less carbonic acid being exhaled, and a smaller amount of oxygen absorbed; just the opposite effect as was observed to follow the addition of uric acid to blood.

The subjoined Table shows this more distinctly.

Sheep's blood. Twenty-four hours. 100 per cent. of air.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
Pure blood	13·90	1·95	84·15	15·85
Blood plus uric acid	13·17	2·62	84·21	15·79
Blood plus sugar	15·01	1·61	83·38	16·62

Action of Vegetable Products on Blood.

Hydrocyanic Acid.

The following are examples of the influence of hydrocyanic acid on the action of blood on the respiratory gases.

A quantity of perfectly fresh ox-blood was taken and carefully switched until freed, as far as possible, of its fibrin. After being thoroughly arterialized, it was then divided into several portions of 62 grammes each, and treated in the usual manner in a room of moderate temperature during twenty-four hours.

Pure defibrinated ox-blood with 100 per cent. of atmospheric air. Twenty-four hours' action. Result:—

No. 35.—In 100 parts of air.

Oxygen . . .	10·42	Total oxygen 15·47
Carbonic acid . .	5·05	
Nitrogen . . .	84·53	

Defibrinated ox-blood with 6 drops (20 per cent. strength) of hydrocyanic acid. 100 per cent. of air. Twenty-four hours' action. Result:—

No. 36.—In 100 parts of air.

Oxygen . . .	16·32	Total oxygen 18·23
Carbonic acid .	1·91	
Nitrogen . . .	81·77	

It is thus seen that the effect of hydrocyanic acid is to retard those transformations and decompositions upon which the interchange of the respiratory gases depend. The effect is well marked in this case, but it is even more so in a case of poisoning in the human subject, which I shall immediately refer to; meanwhile the results of these two analyses are—

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 per cent. of air from pure ox-blood......	10·42	5·05	84·53	15·47
Ditto plus hydrocyanic acid	16·32	1·91	81·77	18·23

Action of Hydrocyanic Acid on Human Blood.

A quantity of blood was removed from the heart and great vessels of a healthy well-developed young woman, aged 19 years, who died within half an hour after swallowing a couple of drachms of bitter almond oil. The blood was still fluid forty-eight hours after death, and yielded a small quantity of hydrocyanic acid by distillation. A portion of the blood, after being thoroughly arterialized by agitation with renewed portions of air, was put into a receiver with 100 per cent. of atmospheric air, and kept twenty-four hours (with occasional agitation) in a room of an average temperature of 15° C. At the end of the twenty-four hours the air confined with the blood was analyzed, with the subjoined result:—

No. 37.—In 100 parts of air.

Oxygen	19·56
Carbonic acid	0·00
Nitrogen	80·44

It is here seen that the effect of hydrocyanic acid is the same in the body as out of it, namely, to arrest respiratory changes.

Nicotine.

Various experiments were performed with nicotine, and it was invariably found to produce the same result; namely, to retard the normal oxidation processes in blood, and at the same time to diminish the exhalation of carbonic acid. The following experiment may be quoted as an illustration of the fact.

Two portions (62 grammes) of defibrinated ox-blood, after being thoroughly arterialized, were placed in receivers with 100 per cent. of atmospheric air, and both were treated during twenty-four hours exactly alike, except that to one was added 6 drops of chemically pure nicotine.

Gas from pure ox-blood after twenty-four hours' action with 100 per cent. of atmospheric air. Result:—

No. 38.—In 100 parts of air.

Oxygen . . .	14·66	Total oxygen 17·04
Carbonic acid . .	2·38	
Nitrogen . . .	82·96	

Gas from ox-blood after twenty-four hours' action with 6 drops of nicotine. 100 per cent. of atmospheric air. Result:—

No. 39.—In 100 parts of air.

Oxygen . . .	19·60	Total oxygen 21·09
Carbonic acid .	1·49	
Nitrogen . . .	78·91	

It is thus seen, as was before said, that nicotine diminishes the power of the blood to take up oxygen and give off carbonic acid, and thereby become fitted for the purposes of nutrition.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 per cent. of air from pure ox-blood......	14·66	2·38	82·96	17·04
Ditto plus nicotine	19·60	1·49	78·91	21·09

Woorara Poison.

Two portions of defibrinated sheep's blood, after being thoroughly arterialized, were placed in receivers with 100 per cent. of atmospheric air, and kept, with occasional shaking, at a temperature of 15° C. during twenty-four hours. The treatment of the two portions of blood only differed in this respect, that to one nothing was added, while 0·01 gramme of woorara was put into the other. The amount of blood in each case was 62 grammes.

Air from pure sheep's blood. Twenty-four hours' action. 100 per cent. of air. Result:—

No. 40.—In 100 parts of air.

Oxygen. . . .	12·42	Total oxygen 13·12
Carbonic acid. .	0·70	
Nitrogen . . .	86·88	

Air from sheep's blood plus woorara. Twenty-four hours' action. 100 per cent. of air. Result:—

No. 41.—In 100 parts of air.

Oxygen. . . .	16·68	Total oxygen 18·28
Carbonic acid. .	1·60	
Nitrogen . . .	81·72	

It is thus seen that woorara has the peculiar effect of diminishing oxidation, and at the same time increasing the exhalation of carbonic acid gas.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 per cent. of air from pure sheep's blood	12·42	0·70	86·88	13·12
Ditto plus woorara	16·68	1·60	81·72	18·28

For the purpose of studying the action of woorara upon the blood of the living animal, I injected under the skin of a dog an aqueous solution of five grains of the poison*. The animal soon became paralyzed and died, as is usual in those cases, from the cessation of the respiratory movements. The heart's action continued vigorous for some time after apparent death: a portion of this dog's blood was then taken and thoroughly arterialized by repeatedly shaking it with renewed quantities of air. The blood was then enclosed in a receiver with 100 per cent. of atmospheric air, and treated in the usual way during twenty-four hours. The result of the analysis was as follows:—

No. 42.—In 100 parts of air.

Oxygen. . . .	18·68	Total oxygen 20·19
Carbonic acid. .	1·51	
Nitrogen . . .	79·81	

If we compare this result with the analysis of air from the blood of a healthy dog (No. 28) already given (page 702), we shall find that the effect of the woorara has been like that of snake poison, to increase the chemical decompositions and transformations in the blood, upon which the exhalation of carbonic acid depend.

* For the woorara employed on this occasion I am indebted to the liberality of CHARLES WATERTON, Esq., of Walton Hall, the well-known author of the 'Wanderings.' He obtained it in Guiana in 1812, and though it is consequently half a century old, it is still an exceedingly active poison.

In 100 parts of air.	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
Healthy blood of dog	19·700	0·409	79·891	20·109
Blood of dog poisoned with woorara ...	18·680	1·510	79·810	20·190

It will be observed that there is a slight discrepancy between the amount of oxygen absorbed in this and the other experiment on the action of woorara out of the body; for here the oxidation has been greater than in the healthy animal. This most probably arises, however, from some accidental cause, due to the blood being taken from different animals and not operated on in the same day. Unfortunately it is impossible to operate on both healthy and poisoned blood of the same animal at the same time, so that all our experiments of comparison on the blood of living auimals are liable to the source of error arising from the state of the body and the constitutional peculiarity of the animal. My former statement regarding the action of woorara, namely, that it diminishes oxidation and increases the exhalation of carbonic acid, at least in sheep's blood, is I have little doubt correct, as I have invariably found it to be so. I might here quote other experiments in proof of this assertion, but in order to prevent unnecessary repetition, shall delay doing so till the action of woorara is compared with that of other substances.

Antiar and Aconitine.

For the sake of brevity I shall take these two poisons together. As is well known, their physiological action on the animal body is, as nearly as possible, identical. They are both powerful cardiac poisons. So powerfully, indeed, do they act in this way, that when given to frogs they stop the action of the heart while the animal is otherwise sufficiently well to be able to spring about. This is the reverse of woorara, which allows the heart's action to continue long after the rest of the body is dead. Hence arises the saying that we may have a dead heart in a living body with antiar and aconitine, and a dead body with a living heart with woorara.

The result of the following experiment forcibly illustrates the truth of the latter statement. A healthy full-grown frog was pricked with the point of a poisoned arrow, and in the course of a few minutes its limbs gradually became paralysed. The paralysis soon extended itself over the body, the animal ceased to breathe, and in the course of a few minutes more was dead. On examining the heart about an hour afterwards, that organ, and that organ alone, was found still alive. Death could not be said here to have usurped its power, for it slowly and regularly pulsated as in life. On the following day the heart still continued to beat although the tissues surrounding it had assumed the appearance of death. Forty-eight hours after the animal had been poisoned its heart still continued to act regularly, and even seventy-two hours afterwards the action of the ventricle and auricles, though feeble, was yet distinct. On the fourth day (ninety-six hours after death) part of the heart died, the left auricle alone continued to pulsate. But now, not only was the frog dead, but its lower limbs were already shrunk and withered. I then made an attempt at resuscitation, and exactly 100 hours after the animal died I put it into a moist warm atmosphere, and there retained it till the temperature of its body was slightly raised. This treatment had the effect of restoring the irritability of the heart, and on touching the ventricle with a point of my pen it resumed its pulsations, and during several minutes the contractions, first of the auricles and then of the ventricles, continued rhythmically; even the pulsations in the large vessels attached to the heart also became distinctly visible, and continued so with regularity for upwards of a quarter of an hour.

The chemical action of antiar and aconitine on the blood, like their physiological action on the nervous system, are as near as possible alike. First, as regards their influence on the exhalation of carbonic acid. Two portions of thoroughly defibrinated and well arterialized sheep's blood, 62 grammes each, were put into receivers with 100 per cent. of air. To the one 0·01 gramme of antiar dissolved in water was added; to the other a similar quantity of pure aconitine dissolved in faintly acid water. After twenty-four hours' action the air in the receivers was analyzed with the following results.

Antiar*, twenty-four hours' action, 100 per cent. of air. Result:—

No. 43.—In 100 parts of air.

Carbonic acid . . . 2·05.

No. 44.—Result of analysis of air from blood with aconitine in 100 parts of air.

Carbonic acid . . . 2·02.

It is thus seen that the influence of antiar and aconitine on the exhalation of carbonic acid is very similar. I shall now quote a series of experiments in which the influence of these substances with that of woorara is compared.

A quantity of defibrinated sheep's blood was taken seventeen hours after the death of the animal, and after being completely arterialized it was divided into four portions, each of which was put into a receiver with 100 per cent. of atmospheric air. They were all treated precisely alike, except that to one 0·092 gramme of antiar was added, to another 0·092 gramme of aconitine, and to a third 0·092 gramme of woorara. The fourth portion was retained pure in order to form a standard of comparison. After twenty-four hours' action the air was analyzed, with subjoined results.

No. 45.—Air from pure blood in 100 parts of air.

Oxygen	13·76	Total oxygen 15·81
Carbonic acid . .	2·05	
Nitrogen . . .	84·19	

* For the antiar employed in these experiments I am indebted to the kindness of Professor Sharpey.

No. 46.—Air from blood plus woorara, in 100 parts of air.

Oxygen	16·85	Total oxygen 19·83
Carbonic acid . .	2·98	
Nitrogen . . .	80·17	

No. 47.—Air from blood plus antiar, in 100 parts of air.

Oxygen	12·98	Total oxygen 13·99
Carbonic acid . .	1·01	
Nitrogen . . .	86·01	

No. 48.—Air from blood plus aconitine, in 100 parts of air.

Oxygen	11·66	Total oxygen 12·96
Carbonic acid . .	1·30	
Nitrogen . . .	87·04	

By placing these results in a tabular form the comparative value of each of the factors will be made more apparent.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of air from pure blood......	13·76	2·05	84·19	15·81
Blood plus woorara	16·85	2·98	80·17	19·83
„ „ antiar	12·98	1·01	86·01	13·99
„ „ aconitine......................	11·66	1·30	87·04	12·96

The similarity in the action of antiar and aconitine, and the dissimilarity between their action and that of woorara, are well illustrated in the above Table. The woorara diminishes oxidation and increases the exhalation of carbonic acid. Antiar and aconitine increase oxidation and diminish the exhalation of carbonic acid gas.

Strychnine.

In order to ascertain the influence of strychnine, a quantity of fresh calf's blood was shaken with renewed portions of atmospheric air until it had become thoroughly saturated with oxygen. It was then enclosed in a receiver with 100 per cent. of ordinary air, corked up, and kept in a room of moderate temperature during twenty-four hours.

A second portion of the same blood (62 grammes) was similarly treated in every way except that it had 0·05 gramme of strychnine added to it. During the twenty-four hours the receivers were as usual frequently agitated to favour the mutual action of the blood and air. At the end of this period the composition of the gas in the receivers was found to be—

Gas from pure calf's blood, twenty-four hours' action with 100 per cent. of air:—

No. 49.—In 100 parts of air.

Oxygen	12·10	Total oxygen 18·04
Carbonic acid . .	5·94	
Nitrogen . . .	81·96	

Gas from calf's blood plus strychnine, dissolved in a minimum of very dilute hydrochloric acid, twenty-four hours' action with 100 per cent. of air:—

No. 50.—In 100 parts of air.

Oxygen	17·82	Total oxygen 20·55
Carbonic acid . .	2·73	
Nitrogen . . .	79·45	

Thus it is seen that strychnine is one of those substances possessing the strange property of preventing the chemical decompositions and transformations of the constituents of the blood upon which the absorption of oxygen and exhalation of carbonic acid depend.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of gas from pure calf's blood	12·10	5·94	81·96	18·04
Ditto plus strychnine	17·82	2·73	79·45	20·55

The next point to determine is, does strychnine act in the same manner on blood in the living animal as out of it?

The results of the two following experiments seem to indicate this, but as they were performed with the view of solving an entirely different question not requiring any controlling experiments, they had none made with them, and therefore they can only be taken for what the results of single experiments are worth.

Into the peritoneal cavity of a healthy full-grown cat was injected a solution of $\frac{1}{20}$th of a grain of strychnine. In five minutes the animal became convulsed, and in four minutes more it died. On opening the body eight minutes after death, some of the blood was found already coagulated in the greater vessels, and the portion that was fluid coagulated as soon as it flowed into a capsule. The blood had a dark purple colour, and when shaken on the sides of a glass looked almost grumous and granular, as if the corpuscles were broken up, and had allowed their contents to escape. Under the microscope plenty of healthy red corpuscles were seen, many of them running into rolls; but besides these, although there were no broken-up cells to be seen yet there were an unusual number of small granules in the field. The animal was fasting, nevertheless there were also a considerable number of white corpuscles present. The blood contained 0·22 gramme of urea to the oz. (0·709 per cent.) and abundance of sugar.

Gas from blood of cat poisoned with strychnine, twenty-four hours' action with 100 per cent. of air in a room of moderate temperature:—

No. 51.—In 100 parts of air.

Oxygen	17·03	Total oxygen 17·63
Carbonic acid . .	0·60	
Nitrogen . . .	82·37	

It is thus seen that the blood of the poisoned animal yields even a smaller quantity of carbonic acid than the blood to which strychnine has been added out of the body, while the quantity of oxygen that has disappeared is the same in both cases.

Brucine.

Besides strychnine the alkaloid brucine is also obtained from nux vomica, and the following experiment was made with the view of testing if it had a similar action upon blood. The experiment in this case, however, was somewhat extended in order to compare its action with that of two other substances, namely, quinine and morphia, and as the results obtained form rather an interesting series, I shall give them consecutively.

A quantity of perfectly fresh calf's blood, after being defibrinated and thoroughly saturated with oxygen by repeatedly shaking it with renewed quantities of air, was divided into several portions of 62 grammes each. To the first nothing was added; to the second 0·005 gramme of brucine; to the third 0·005 gramme of quinine; and to the fourth 0·005 gramme of morphine: these alkaloids were all dissolved by the aid of a minimum quantity of hydrochloric acid. The different portions were then enclosed in receivers with 100 per cent. of air, and treated in the usual manner, with occasional agitation, in a room of moderate temperature during twenty-four hours. At the expiration of that period the air was analyzed, with the following results:—

No. 52.— The air from pure calf's blood contains in 100 parts of air—

Oxygen	6·64	Total oxygen 10·11
Carbonic acid . .	3·47	
Nitrogen . . .	89·89	

The air from the calf's blood plus brucine contained—

No. 53.—In 100 parts of air.

Oxygen	11·63	Total oxygen 13·97
Carbonic acid . .	2·34	
Nitrogen . . .	86·03	

It is thus seen that brucine acts like strychnine, but in a much less marked degree.

Quinine.

As has just been said, to another portion of the same blood as was employed in the two preceding cases, 0·005 gramme of quinine was added.

No. 54.—In 100 parts of air.

Oxygen	14·72	Total oxygen 16·77
Carbonic acid . .	2·05	
Nitrogen . . .	83·23	

Morphine.

To the fourth portion of the same blood 0·005 gramme of morphine dissolved in water acidulated with hydrochloric acid was added, and the result was as follows:—

No. 55.—In 100 parts of air.

Oxygen	17·17	Total oxygen 18·17
Carbonic acid . .	1·00	
Nitrogen . . .	81·83	

It is thus seen that these different substances, Brucine, Quinine, and Morphine, with hydrochloric acid as their solvent, have all acted on the blood in the same manner, retarding oxidation, and decreasing the exhalation of carbonic acid, but in very different degrees. By placing them in a tabular form, the difference in their respective results will be still better appreciated.

	Oxygen.	Carbonic acid.	Nitrogen.	Vol. at 0° C. and 1 metre pressure.
In 100 parts of air:—				
After being acted on by pure blood........	6·64	3·47	89·89	10·11
Ditto by blood plus brucine..................	11·63	2·34	86·03	13·97
„ „ quinine..................	14·72	2·05	83·23	16·77
„ „ morphine..............	17·17	1·00	81·83	18·17
Composition of atmospheric air employed in the experiments........................	20·96	0·002	79·038	20·962

It ought not to be forgotten that the blood in all of these cases was not only taken from the same animal, and the product of one bleeding, but in every respect, both before and after being put into the receivers, subjected to precisely similar influences, under identical conditions. The difference in the results must therefore be regarded as entirely due to the effect of the alkaloids upon the blood.

Action of Anæsthetics on Blood.

Chloroform.

From the fact that of all anæsthetics at present employed chloroform holds the first rank, its action upon blood was carefully studied. The results obtained were exceedingly uniform and all tending to one conclusion, namely, that this substance has a powerful effect in retarding those chemical transformations and decompositions upon which the process of respiration depends.

1st. As regards the visible effect of chloroform upon blood.

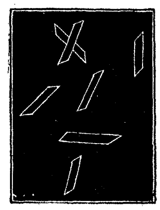
If 5 per cent. of pure chloroform be mixed with the freshly-drawn blood of a healthy animal, it will be found that within half an hour the blood will assume a brilliant scarlet hue. If the vessel containing it be now agitated, so as to mix the blood with atmospheric air, a quantity of colouring-matter adheres to the sides of the glass, and on allowing it again to stand for a few minutes, a red somewhat flocculent precipitate is deposited. This precipitate is not hæmatin alone. On the contrary, it consists of a dirty red-coloured protein substance, whereas the dissolved or suspended pigment has a vermilion hue. If the blood be kept at rest for some hours—laid aside during the night—it will to a certain extent lose its brilliant colour, and assume that of the red precipitate previously spoken of. At the same time it will be found to solidify into a gelatinous sticky paint-like mass. If instead of 5 per cent., 50, or still better 100 per cent. of chloroform, be added to venous blood either defibrinated or non-defibrinated, it causes it at once to assume the arterial hue, and this is still more marked if the vessel be well agitated. The blood rapidly solidifies and retains its vermilion tint for many hours, even days. It not unfrequently happens that blood to which chloroform has been added crystallizes on solidifying, more especially when only 5 per cent. of chloroform is used.

Serum is not solidified by chloroform in the same way, but it deposits a white precipitate.

2nd. Microscopical appearances presented by blood after being acted upon by chloroform.

If 5 per cent. of chloroform be added to blood, and the mixture well shaken, it will be found on examining it with the microscope that, although very many of the red corpuscles have disappeared, their walls having been dissolved, and their contents escaped, the great majority of them remain intact. Even 100 per cent. of chloroform fails to destroy totally the blood-cells. Great numbers of the red cells are, however, destroyed, and their contents diffused throughout the liquid. It is indeed the contents of the red corpuscles that crystallize. The crystals are in many cases quite red. They are prismatic in shape, and about four times as long as they are broad. The crystals are always most readily obtained from the blood of animals that have been poisoned with chloroform, but only after an additional quantity is added. They are insoluble in chloroform, ether, alcohol, and water.

Fig. 3.



Crystals obtained from blood by means of chloroform.

3rd. Chemical action of chloroform on blood.

Two equal portions of defibrinated and arterialized ox-blood, equal to 62 grammes each, were placed in receivers with 100 per cent. of atmospheric air, and kept in a room of moderate temperature during twenty-four hours. Both bloods were treated precisely alike, except that while the one was kept in its normal state, the other had three drops of chloroform added to it.

Gas from pure ox-blood, twenty-four hours' action with 100 per cent. of atmospheric air:—

No. 56.—In 100 parts of air.

Oxygen	10·42	Total oxygen 15·47
Carbonic acid . .	5·05	
Nitrogen . . .	84·53	

Gas from ox-blood plus chloroform, twenty-four hours' action, 100 per cent. of atmospheric air :—

No. 57.—In 100 parts of air.

Oxygen	18·76	Total oxygen 20·64
Carbonic acid . .	1·88	
Nitrogen . . .	79·36	

This result proves that chloroform possesses the property of diminishing the power of the constituents of the blood to unite with oxygen, and give off carbonic acid. A precisely similar result was obtained when the experiment was made on the blood of the young animal.

Perhaps as chloroform is so important an agent I may be pardoned quoting an experiment performed on the blood of the calf, which proves the correctness of the above assertion.

Equal parts of well-oxygenated freshly-defibrinated calf's blood were treated during twenty-four hours in receivers in the usual way. One was kept pure, and the other had three drops of chloroform added to it (as in the other cases the quantity of blood employed was 62 grammes).

Gas from pure calf's blood, twenty-four hours' action, with 100 per cent. of atmospheric air :—

No. 58.—In 100 parts of air.

Oxygen	12·10	Total oxygen 18·04
Carbonic acid . .	5·94	
Nitrogen . . .	81·96	

Gas from calf's blood plus chloroform, twenty-four hours' action, with 100 per cent. of atmospheric air. Result :—

No. 59.—In 100 parts of air.

Oxygen	18·05	Total oxygen 20·93
Carbonic acid . .	2·88	
Nitrogen . . .	79·07	

It is thus seen that chloroform acts in the same manner on the blood of the young as on that of the adult animal.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of air from				
Pure ox-blood	10·42	5·05	84·53	15·47
Ditto plus chloroform	18·76	1·88	79·36	20·64
Pure calf's blood	12·10	5·94	81·96	18·04
Ditto plus chloroform	18·05	2·88	79·07	20·93

Ether.

The action of sulphuric ether, which is also used as an anæsthetic, upon blood is both chemically and physically different from that of chloroform, as shown by the result of the following experiments.

1st. Chemical effect of ether upon blood.

A quantity of ox-blood, after being defibrinated and well saturated with oxygen in the usual way, was divided into several portions, to one of which nothing was done, while to another 5 per cent. of sulphuric ether was added. After the different portions of blood had been kept with 100 per cent. of atmospheric air during twenty-four hours, in a room of moderate temperature, they yielded the subjoined results.

Gas from pure ox-blood, twenty-four hours' action, 100 per cent. of air yielded—

No. 60.—In 100 parts.

Oxygen	10·58	Total oxygen 14·91
Carbonic acid . .	3·33	
Nitrogen . . .	86·09	

Gas from ox-blood plus 5 per cent. of sulphuric ether, twenty-four hours' action, 100 per cent. of air. Result:—

No. 61.—In 100 parts of air.

Carbonic acid . . 3·40

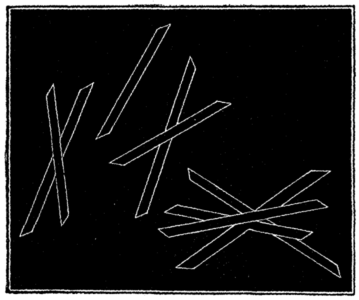
In the experiments with ether the amount of oxygen absorbed by the blood could not be ascertained in consequence of the gas in the eudiometers refusing to explode. Even after the tubes were nearly filled with explosive gas the electric spark failed to ignite the gas, yet when the eudiometers were removed from the mercury trough, the gases instantly and violently exploded on the application of a lighted match.

2nd. Physical effects of ether upon blood.

When 5 per cent. of ether is added to fresh blood no marked effect is observed, except that the blood does not arterialize so readily as with chloroform. When ten, twenty, or more per cent. is added, the difference in the physical effect of the two anæsthetics upon blood is very striking. The etherized blood becomes clear but dark in colour, and cannot be made to assume the perfect arterial tint, not even after prolonged agitation with renewed portions of atmospheric air. The greater the percentage of ether the more visible is this effect. 100 per cent. of sulphuric ether gives to blood a beautifully rich transparent port-wine colour. When left some hours in repose, part of the ether separates from the blood and floats as a colourless liquid on the surface, while the blood itself still retains the rich dark hue, except the layer in immediate contact with the ether, which appears as if it had a vermilion tint. When examined with the microscope the blood-corpuscles are found to be completely destroyed, their colouring-matter being set free.

When non-defibrinated blood is employed, and the ether allowed to evaporate, the blood solidifies, and in so doing frequently crystallizes; but strange to say the crystals are quite different in form from those obtained by chloroform from the same blood. They are long needles, twelve times as long as broad, and are sometimes so abundant that they fill up the whole field of the microscope. The crystals are not usually so much coloured as those of chloroform. They too are most copious in the blood of animals poisoned by the anæsthetic. In some healthy bloods I have entirely failed in detecting them. The best are obtained from the blood of the dog*. Ether, as already said, destroys the corpuscles more than chloroform.

Fig. 4.



Crystals obtained from blood by means of ether.

It is curious to notice how the effects of different substances upon blood vary. I thought, for example, that alcohol would act like ether upon blood, whereas to my surprise its action much more closely resembled that of chloroform, although only in a mitigated degree. Notwithstanding that alcohol cannot properly be regarded in the light of an anæsthetic, I shall take the liberty of here introducing an experiment upon it, seeing that it was performed on a portion of the same blood as served for the last two examples, and was conducted under precisely similar circumstances. Five per cent. of pure alcohol was employed.

Alcohol.

Gas from ox-blood plus alcohol, after twenty-four hours' action, on 100 per cent. of atmospheric air:—

No. 62.—In 100 parts of air.

Oxygen	16·59	} Total oxygen 18·97
Carbonic acid . .	2·38	}
Nitrogen . . .	81·03	

By placing the results of these last three experiments in a tabular form the difference they present will be better seen.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of air from				
Pure blood.....................	10·58	3·33	86·09	14·91
Ditto plus ether	......	3·40		
Ditto plus alcohol	16·59	2·38	81·03	18·97

It is thus seen that while the action of ether is to increase, or at least not to diminish

* Magnificently large prismatic crystals are readily obtained by adding equal parts of ether to the blood of dogs poisoned by the vapour of chloroform. They are of a fine red colour, and many of them appear to be formed of bundles of needle-shaped crystals. Sometimes almost the whole blood crystallizes.

the transformations occurring in blood upon which the exhalation of carbonic acid depends, that of alcohol, on the other hand, is to restrain these, as well as to diminish the consumption of oxygen:—a similar effect, it will be remembered, to that which occurs with chloroform; the only difference being that the action of alcohol is very much less powerful, for a less quantity of chloroform produces a much greater effect.

Physical effect of Alcohol upon Blood.

When blood is shaken with 10 per cent. or more of alcohol it becomes of a light brick-red hue. The albumen is coagulated and subsides to the bottom of the vessel. No amount of shaking with renewed portions of air will properly arterialize blood mixed with alcohol, nor have I ever obtained any crystals from blood so treated, not even from that of animals poisoned by chloroform. Alcohol does not destroy the blood-corpuscles nor set the hæmatin free.

Amylene.

Some years ago amylene was proposed as an anæsthetic for the purpose of annulling pain in surgical operations, but owing to its disagreeable odour, or some other cause, it has never come into general use. Several experiments were made with this substance.

1st. As regards its physical action upon blood.

When five per cent. of amylene is added to fresh blood, and the mixture well shaken, the blood assumes a dark-red tint, and does not arterialize readily. When 100 per cent. of the anæsthetic is employed, the blood becomes quite black, and when spread out in a thin layer has a dirty brownish-red appearance. It cannot now be made to arterialize at all. If the mixture be allowed to stand for twenty-four hours, the amylene in great part separates from the blood, and floats in a clear layer on its surface. The blood, however, still retains its black, thin, tarry-like aspect.

When examined with the microscope, the red corpuscles are found beautifully distinct; none appear to be destroyed, and no blood-crystals are to be found. Indeed the formation of the crystals seems to be in proportion to the destruction of the corpuscles.

2nd. Chemical action of amylene upon blood.

Two portions of defibrinated sheep's blood, after being saturated with oxygen in the usual manner, were placed in receivers, the one with nothing, the other with four drops of amylene to the 62 grammes of blood. After twenty-four hours' action the gases were analyzed in the usual way; but on attempting to estimate the oxygen in the air enclosed with the amylene, it was found impossible to obtain an explosion, not only after the mere addition of hydrogen, but after a large amount of explosive gas had been added to the mixture; and what was more extraordinary still, the electric spark even failed to produce any explosion after the sulphuric acid and potash balls had been employed. On inverting the eudiometer the gas was found to smell strongly of amylene, and there can be little doubt but that its presence prevented the explosion taking place. The analysis of the gas, as far as it went, was as follows:—

Gas from sheep's blood plus amylene, twenty-four hours' action, 100 per cent. of atmospheric air:—

No. 63.—In 100 parts of air.

Carbonic acid	0·62

Whereas the air from pure blood gave quite a different result.

Gas from pure sheep's blood after twenty-four hours' action, 100 per cent. of air:—

No. 64.—In 100 parts of air.

Carbonic acid	3·17

It thus appears that amylene has a marked effect in diminishing the exhalation of carbonic acid gas.

Action of Mineral Substances on Blood.

Chloride of Mercury (*Corrosive sublimate*).

The experiments with mineral products were in general conducted in the same manner as those with other substances. In the present instance, however, the experiment was like some of the exceptions previously related, slightly modified, and instead of employing defibrinated blood, the blood was put into the receivers direct from the animal. Calf's arterial blood was used in this case, and as it slightly coagulated in the vessels, it was found necessary to have them well shaken (before being definitely closed) until the coagula were all broken up. While to one of the portions of blood nothing was done, to the others 6 drops of a saturated aqueous solution of corrosive sublimate were added. The quantity of blood employed in each case amounted to 40 grammes, and the air confined with it to 150 per cent. The receivers were all treated alike, during twenty-four hours, in a room of moderate temperature. At the end of that time a marked difference was observed in the bloods. The pure blood still retained its arterial tint, while that to which corrosive sublimate had been added was of an intensely dark, almost black colour. Moreover the latter had separated into two layers, a thin dark red liquid, and a somewhat gelatinous coagulum. The dark liquid part of the blood felt quite sticky to the fingers.

Gas from pure calf's blood after twenty-hours' action with 150 per cent. of atmospheric air:—

No. 65.—In 100 parts of air.

Oxygen . . .	16·57	Total oxygen 18·72
Carbonic acid .	2·15	
Nitrogen . . .	81·28	

Gas from calf's blood plus corrosive sublimate, twenty-four hours' action, 150 per cent. of atmospheric air:—

No. 66.—In 100 parts of air.

Oxygen . . .	17·01	Total oxygen 20·59
Carbonic acid . .	3·58	
Nitrogen . . .	79·89	

It is thus seen that corrosive sublimate, while increasing the changes which develope carbonic acid, has an almost negative effect on those depending upon oxidation; if anything rather diminishing them than otherwise.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of air from pure blood	16·57	2·15	81·28	. 18·72
Ditto plus corrosive sublimate	17·01	3·58	79·89	20·59

I may here take occasion to mention a fact in connexion with the physiological effects of corrosive sublimate on the animal body, which, as far as I am aware, has hitherto escaped notice, namely, *its cardiac action.* As we have already seen, there exist in the vegetable kingdom substances which, in consequence of their acting specially on the heart and lungs, have acquired the title of cardiac and respiratory poisons; few are, however, aware that in the mineral kingdom there are also substances to be met with, the peculiar action of which on the animal body is such as to entitle them with equal justice to the name of cardiac and respiratory poisons. Corrosive sublimate is an example of the former, protosulphate of iron of the latter.

In order not to be misunderstood, I shall briefly quote the following experiments to illustrate my meaning.

1st. As regards protosulphate of iron, a respiratory poison.

1st experiment. Into one of the jugular veins of a dog was slowly injected an aqueous solution of 15 grains of the protosulphate of iron. In sixty seconds from the commencement of the experiment (which of itself lasted about forty seconds) the animal manifested symptoms of impending suffocation. These speedily induced a convulsion, and the involuntary passage of the contents of the bladder and rectum, as is seen to occur in cases of true apnœa from a mechanical obstruction to the entrance of air into the lungs.

In eight minutes there was complete loss of sensation and voluntary motion. The limbs were paralysed, and the animal manifested no sign of pain on being pinched.

In ten minutes the symptoms of poisoning began to pass away, and in a few minutes more he was again upon his legs. When seen fifty minutes after the commencement of the operation, he was running about apparently quite well.

2nd experiment. Two days later, into the other jugular vein of the same dog, was injected an aqueous solution of 30 grains of the protosulphate of iron, double the quantity first used. Symptoms of suffocation instantly manifested themselves. The lungs did not act. The respiratory movements ceased. But the heart went on beating, and continued to do so for at least three or four minutes after all attempts at respiratory efforts had entirely stopped.

On opening the animal, the heart was found distended with fluid blood. The blood coagulated after its withdrawal from the body. On puncturing the right ventricle, a globule or two of air escaped; but the organ contained no frothy air, nor was there any reason to suppose that the air had been injected during the operation. On the contrary, it appeared as if it had been separated from the blood itself, as occasionally occurs in cases where the blood-vessels are unopened. The urine of the animal contained a large amount of the poison. It is on the above grounds that I consider that the protosulphate of iron merits the title of a respiratory poison. This will be made still more apparent by comparing the foregoing with the result of the following experiment.

2nd. As regards corrosive sublimate, a cardiac poison.

Into the femoral vein of a pregnant bitch was injected an aqueous solution of five grains of corrosive sublimate. In ten seconds the animal cried as if in pain; in sixty she became delirious; and in three and a quarter minutes after the operation was commenced the heart stopped. Neither was there an impulse to be felt on the application of the finger to the femoral artery, nor a sound to be heard on the application of the ear to the thoracic walls. The animal, however, still respired, and continued to make gasping respiratory efforts for thirty seconds more. They then ceased. In three-quarters of a minute after the cessation of respiration the thorax was opened, with the view of ascertaining the conditon of the heart. It was found still; and neither the stimulus of the cold air, of the point of the knife, nor of a feeble current from the galvanic forceps caused it to pulsate.

Ten minutes after death a stronger galvanic current was applied to the organ, but even then the portions between the points of the forceps alone contracted. No general pulsation could be reinduced. The fœtuses were alive and moving about in the uterus twelve and a half minutes after the death of the mother.

The corrosive sublimate had acted specially upon the heart; for the spontaneous peristaltic movements of the intestines were well marked, and continued to be so for twenty-two minutes. The thoracic muscles also contracted spontaneously, with a flickering movement, for no less than thirty minutes. They even responded to the direct application of galvanism for two hours and thirty-five minutes after the death of the animal.

Galvanism applied to the brachial plexus fifteen minutes after death caused violent muscular contractions in the limb supplied by it; yet, as was before said, the heart failed to respond to mechanical and galvanic stimuli applied within a single minute after death.

It appears to me, therefore, that corrosive sublimate merits the name of a cardiac poison quite as much as either aconitine or antiar.

Arsenic.

In testing the action of arsenic, as in the case of corrosive sublimate, non-defibrinated freshly-drawn arterial blood was employed, and the quantity of air with which it was enclosed also amounted to 150 per cent. In this instance, however, dog's instead of calf's blood was employed; and in order to give to the experiment all possible exactitude, while one of the portions of blood had 120 drops of a saturated aqueous solution (by boiling) of arsenious acid added to it, the other was treated to a similar amount of distilled water. In all other respects they were treated precisely alike, both before and after the twenty-four hours' action.

Gas from non-defibrinated fresh dog's blood plus 120 drops of distilled water, twenty-four hours' action with 150 per cent. of atmospheric air:—

No. 67.—In 100 parts of air.

Oxygen . . .	20·376	Total oxygen 21·357
Carbonic acid .	0·981	
Nitrogen . . .	78·643	

Gas from dog's blood plus arsenious acid, twenty-four hours' action with 150 per cent. of atmospheric air:—

No. 68.—In 100 parts of air.

Oxygen . . .	21·270	Total oxygen 21·538
Carbonic acid .	0·268	
rogen . . .	78·562	

It is thus seen that arsenious acid is one of those substances which retard the transformation of the constituents of the blood on which the absorption of oxygen and exhalation of carbonic acid in the respiratory process depend.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of air from pure dog's blood ...	20·376	0·981	78·643	21·357
Ditto plus arsenic	21·270	0·268	78·562	21·538
Pure atmospheric air	20·960	0·002	79·038	20·962

A precisely similar result was obtained with defibrinated calf's blood.

Tartrate of Antimony.

A quantity of well-defibrinated sheep's blood, after being thoroughly saturated with oxygen, was divided into several portions, and while one was left in its normal condition, 0·02 gramme of tartrate of antimony was added to another (the quantity of blood employed in each case was 62 grammes). The blood was treated in the usual manner, in receivers with 100 per cent. of air, during twenty-four hours.

Gas from pure sheep's blood, after twenty-four hours' action with 100 per cent. of atmospheric air:—

No. 69.—In 100 parts of air.

Oxygen . . .	19·262	Total oxygen 21·08
Carbonic acid .	1·818	
Nitrogen . . .	78·920	

Before treatment the blood contained 0·451 per cent. of urea; after treatment it contained 0·435 per cent.

Gas from sheep's blood plus tartrate of antimony, twenty-four hours' action, 100 per cent. of atmospheric air:—

No. 70.—In 100 parts of air.

Oxygen . . .	20·41	Total oxygen 22·96
Carbonic acid .	2·55	
Nitrogen . . .	77·04	

Before treatment this blood contained 0·451 per cent. of urea; after treatment it contained 0·354 per cent. In another portion of this blood, which was treated with sulphate of zinc, there remained only 0·28 per cent. of urea. In a series of experiments on the effects of antimony as a slow poison, I invariably found the urine loaded with urea, even when the animals were reduced to perfect skeletons. In the urine of a dog that died on the forty-third day after taking half a grain of antimony daily, there was such an amount of urea, that, on adding nitric acid, the whole urine solidified into one mass of crystals. The liver contained neither sugar nor glucogene.

In the above case tartrate of antimony is seen to diminish oxidation, and in a very marked degree to increase the exhalation of carbonic acid gas. The total amount of oxygen is also increased, making it thereby appear as if oxygen had been developed from some one or other of the constituents of the blood, either while they were being pulled down, or built up into new compounds. The apparent increase of the oxygen may be due, however, to another cause, namely, the disappearance of nitrogen from the air.

	Oxygen.	Carbonic acid.	Nitrogen.	Total oxygen.
In 100 parts of atmospheric air	20·960	0·002	79·038	20·962
Air from pure blood......................	19·262	1·818	78·920	21·080
Ditto plus antimony	20·41	2·55	77·04	22·96

This increase in the total amount of oxygen, or decrease in the amount of nitrogen, was even much more decided in another experiment with antimony on sheep's blood. In it the oxygen actually amounted to 24·69 per cent., and the nitrogen stood at 75·31 per cent.

In concluding this paper, it was my intention to make some remarks on the reciprocal action of hæmatin and atmospheric air; for, as stated in a communication on the condition of ox gen absorbed into the blood during respiration*, which I had the honour of making to the Royal Society some years ago, the colouring-matter of the blood appears to possess a more powerful effect in altering the composition of atmospheric air than any other individual constituent of that liquid. The recent researches of Professor STOKES, however, cause me to pause before again publishing my views on animal colouring-matters. For the interesting results obtained by that gentleman with the prism, although in accordance with my facts, may nevertheless induce me to modify my theory; not regarding the action, but regarding the nature of these substances. I have hitherto held the view that all the animal pigments spring from one colourless radical, and that the difference in tint between hæmatin, urohæmatin, and biliverdin was simply due to the different stages of oxidation of the radical. It would appear, however, from the researches of Professor STOKES, that all these substances, although closely allied, are nevertheless chemically distinct. I consequently prefer reinvestigating the subject before communicating to the Society the data which are at present before me.

* Proceedings of the Royal Society, vol. viii. p. 82.