Inaugural dissertation on the presence of air in the organs of circulation, submitted to the Medical Faculty of the University of Edinburgh, in conformity with the rules for graduation, by authority of the Very Rev. Principal Baird, and with the sanction of the Senatus Academicus / by John Rose Cormack.

PRIZE THESIS.

INAUGURAL DISSERTATION

ON THE PRESENCE OF

AIR IN THE ORGANS OF CIRCULATION,

SUBMITTED TO

The Medical Faculty of the University of Edinburgh,

IN CONFORMITY WITH THE RULES FOR GRADUATION,

BY AUTHORITY OF

THE VERY REV. PRINCIPAL BAIRD,

AND WITH THE SANCTION OF

THE SENATUS ACADEMICUS.

BY

JOHN ROSE CORMACK,

PRESIDENT OF THE ROYAL MEDICAL SOCIETY OF EDINBURGH, &c.

AND CANDIDATE FOR THE

DEGREE OF DOCTOR IN MEDICINE.

EDINBURGH:

JOHN CARFRAE & SON, SOUTH BRIDGE;

LONGMAN, ORME, BROWN, GREEN, AND LONGMAN, LONDON;

HODGES AND SMITH, DUBLIN.

MDCCCXXXVII.

Edinburgh: Printed by Balfour & Jack, Niddry Street.

"Faire ladye! that ayre is most killinge. It heth a strange and subtile influence o'er the hart."

Old Play.

TO

THE REV. JOHN CORMACK, D.D.

MINISTER OF STOW,

THIS INAUGURAL DISSERTATION

IS AFFECTIONATELY DEDICATED

BY HIS SON,

THE AUTHOR.

CONTENTS.

INTRODUCTION.

THE amount of physiological knowledge derived from experiments on the inferior animals, would unquestionably have been more extended and accurate than it really is, had experimenters been more desirous to give exact accounts of what they saw, and less anxious to form ingenious hypotheses, and hasty generalizations of facts. It is to be lamented, that this itching after novelty has led some most distinguished men to commit another and a much more serious error than that to which reference has now been made —I allude to a practice with which the French in particular are chargeable, viz. that of describing their experiments in inflated language, using fanciful and exaggerated expressions in recording the effects of the various physiological agents they have employed; thus rendering their observations in a great measure useless, indeed in some cases it may be, worse than useless.

Much unnecessary slaughter of animals might certainly be avoided, were experimenters more careful to record their observations in that plain unvarnished language, which alone

is suited to scientific details. This observation has been naturally suggested by the consideration of the subject of the following Essay.

Bichat exceedingly exaggerated the deleterious effects produced upon the animal economy by the introduction of air into the veins, asserting that a bubble of air introduced into a vein occasioned immediate death. This statement the subsequent experiments of Nysten, Magendie, Dr. Blundell, and others, have proved to be utterly erroneous. Nysten found that a small quantity of all the various gases with which he experimented, including nitrous gas and sulphureted hydrogen, might be introduced into the circulation without occasioning death,* and as will appear from experiments afterwards to be detailed, I have injected large quantities of air into the veins of dogs and rabbits, without the manifestation of any decided effect.

For the sake of perspicuity, it seems necessary to arrange the great variety of topics to which our attention is demanded, under some leading heads, and with this view the following Essay is divided into four chapters, each being to a certain extent a separate Essay.

* Rech. de Physiol. et Chimie Pathol. p. 152. Paris, 1811.

INVESTIGATION,

&c.

CHAPTER I.

EXAMINATION OF THE PHYSIOLOGICAL CHANGES WHICH TAKE PLACE IN THOSE CASES IN WHICH DEATH IS THE ALMOST IMMEDIATE RESULT OF THE ADMISSION OF AIR.

When air or any gas is introduced into the circulation *in sufficient quantity to cause rapid death*, the symptoms which precede the fatal event, are in general pretty uniform, as are also the appearances observed on dissection. The animal suddenly falls down, utters some cries, and speedily expires in convulsions. The most striking and constant phenomenon observed after death, is the presence of air and frothy blood in the heart, and also very frequently in every part of the circulatory apparatus.

There are a number of cases on record of patients dying on the operating table, from air entering a divided vein; and many other instances of sudden and unexpected death in similar circumstances, which were at the time of their

occurrence considered inexplicable, may, probably, with correctness, be referred to this cause; and some instances of sudden death after parturition are now occasionally explained on the supposition of air entering by the uterine sinuses. The not unfrequent occurrence of these untoward events renders our subject one of peculiar interest, independent of that which must ever be excited by the examination of so curious a point in physiology; for the important inquiry is naturally suggested, can nothing be done in such emergencies? But this question cannot be satisfactorily answered at present; for till we have seen the order in which the vital processes are arrested, we cannot hope to be able to discover a method of averting this catastrophe.

The baneful effects of the injection of air into the blood vessels were known to Wepfer and others among the older pathologists,* but it was Dupuytren who first pointed it out as the cause of some of those sudden deaths which take place during surgical operations, and since his observations on this subject have been published, a number of such cases have been described by surgeons in Great Britain, on the Continent, and in America.

Wepfer killed an ox by blowing into the jugular vein, and is believed to be the first who made such an experiment.

As far as I am aware, the physiological effects caused by the introduction of air into the veins, were first made the subject of experiment in this country by Brown Langrish, and described by him to the Royal Society of London about the year 1746. This enthusiastic experimental physiolo-

* The following, among the older authors, have noticed this subject, viz. Wepfer, Redi, Bohn, Vander, Camerarius, Brunner, Harder, Sproegel, Lieutand, Morgagni, Spallanzani, Valsalva, Rudolphi, &c.

gist arrived at the conclusion to which Nysten so long afterwards came, viz. that the circulation is arrested in the heart.

Langrish, upon opening the thorax of a dog, which he had killed in a few seconds by "propelling sulphurous air towards the heart" through the jugular vein, found the right auricle and ventricle greatly distended with air and almost destitute of blood. The cavities of the left side were collapsed. Believing "that the death of the dog was owing to the resistance which the air gave to the return of the blood through the venae cavae, and not to any particular action of the sulphureous fumes on the blood itself," he threw a similar quantity of pure air into the jugular vein of another dog, and found that death ensued as suddenly as in the previous case.* As there is no account given of the post mortem appearances, we may conclude that they were similar to those found in the first experiment.

In more recent times the subject has been investigated by Bichat, Magendie, Nysten, Piednagel, Leroy, Wing, and others. There is a great deal of discrepancy of opinion among these authors, and we shall now examine the respective merits of the various theories which they have propounded.

Bichat believed that death was occasioned by the contact of air with the brain; Nysten maintains that the arrestment of the vital functions depends upon the distension of the right side of the heart with air—that death commences at the right side, and that the cessation of the contractions of the left is a secondary result. Leroy at one time supposed that emphysema of the lungs is the sole cause of death; but he afterwards modified this opinion, and sug-

* Physical Experiments upon Brutes, p. 152. Lond. 1746.

gested the three following ways in which death may take place from the introduction of air into the veins: 1st, By affecting the sensibility of the brain, or by acting mechanically upon that organ: 2d, By producing sudden emphysema of the lungs: and, lastly, By depriving the heart of arterial blood. Piednagel conceives that a change in the structure of the lungs is the principal cause of death.*

Magendie at one time held that emphysema of the lungs was one of the causes of death; but as he does not allude to it in the most recent publication where he notices this subject, it seems probable that he now agrees with Nysten, especially as he brings forward nothing but what indicates such an acquiescence.

The opinion of Bichat, that the air acts as a poison on the brain, appears to have been the result of hasty or inaccurate observation; an opinion which we seem fully warranted in expressing, when we find this distinguished physiologist stating so egregious an error as that a single bubble of air produces an instantaneously fatal result. This theory is based upon the following facts and observations: 1st, The circulation goes on for some time after the introduction of air into the veins: 2d, Air propelled upon the brain through one of the carotids causes death: 3d, Convulsions precede death: 4th, The venous capillaries are full of blood mixed with air; and, fifthly, He considers the cases of sudden death mentioned by Morgagni, in which air was found in the vessels of the brain, as strengthening his theory.

Subsequent inquiries appear to give almost no support to

* Journ. de Physiol. Tome ix p. 79, et seq

the views of Bichat; and indeed these statements furnish but a poor foundation for the sweeping theory which he has attempted to rear upon them. Perhaps his strongest fact is, that death is preceded by convulsions;—phenomena which must unquestionably arise in consequence of an impression made upon the central organs of the nervous system. But then, it may be fairly asked, are not these convulsions *secondary* results? They occur in almost every case of violent death, and in numerous instances can be clearly traced to a primary affection of the heart or lungs. Leroy alleges that convulsive movements are rarely to be witnessed. It may occasionally happen that they are not seen, but I am perfectly satisfied that, in at least the great majority of cases, they do take place. In most of the cases in the human subject, which occurred during operations, there is express mention made of them, (as well as in experiments made upon animals); and when the circumstance is not noticed we have no right to conclude that it did not take place. I have been assured by my friend Mr. Dick of the veterinary school of this place, that although he has killed many horses by blowing air into the veins, he does not recollect of a single instance in which death was not preceded by violent convulsions. But be this as it may, the presence of the phenomenon in question cannot be held as proving that the brain is the organ primarily affected; for it is obvious, that in whatever manner the supply of blood to the brain is suddenly diminished convulsions follow.

The notion of some, that a sudden emphysema of the lungs is the cause of death, at first sight appears plausible, and is certainly very ingenious; but upon examina-

tion it will, I think, be found untenable. When a large quantity of air was thrown directly into the right auricle by Piednagel and Magendie, the former states that respiration all at once ceased, and the heart's pulsations became strong and rapid. On dissection, the lungs were emphysematous and the right side of the heart distended with air, the left cavities containing only a little frothy blood.

Piednagel gives the following account of the manner in which he supposes these appearances to be produced. He conceives that the air contained in the air cells, by means of its pressure prevents that mixed with the blood in the minute ramifications of the pulmonary artery from passing onwards; that this resistance which the heart meets with in attempting to propel the blood through the lungs, acts as a stimulus upon it, and by redoubling the force of its contractions, breaks up the tissue of the lungs. It is urged as an argument in favour of emphysema being the cause of death, that air when introduced gradually and in small quantities produces very slight effects. But it is obvious that it by no means follows, that when death does suddenly take place from the entrance of a large quantity of air, it is caused by emphysema of the lungs. In the first place, emphysema is far from being a constant appearance, as will appear from cases and experiments to be detailed; and when found it can be accounted for in a much more simple way than that proposed by Piednagel.

Dr. Wing killed a rabbit in a few seconds by the forcible injection of air into the external jugular vein, and upon opening the chest the lungs were found collapsed; and besides it is stated, that in every respect they were in

a natural condition.* I have suddenly distended the right auricle in the manner described by Magendie and Piednagel, but emphysema of the lungs was hardly ever observed, though the experiment was often repeated. In one or two cases the structure of the lungs certainly seemed somewhat broken up, but this might be, and in all probability was, produced by the convulsive attempts at respiration which preceded death, just as happens in many cases of poisoning with strychnia and other substances.

No one, so far as I am aware, has attempted to shew that the amount of emphysema found in animals killed with air, is sufficient of itself to produce a sudden and violent death. Till this is done, the theory of Leroy, and others on this subject, must be considered visionary, since all the facts with which we are acquainted, are obviously opposed to it.

It is impossible to distinguish between old and recent emphysema, so that in some of the instances in which it has been found, there is reason to suppose that it may have been of some considerable standing. We know that people with very extensive emphysema of the lungs, may attain an advanced old age without necessarily suffering any great inconvenience, but what bears still more upon this point is, that extensive and sudden emphysema is often occasioned by a fit of whooping cough, and yet we see no symptoms produced analogous to those caused by the entrance of air into the veins. From all these considerations, then, the hypothesis of Leroy, Magendie, and others on this subject, appear wholly unsupported by facts, and must consequently be abandoned.

* Boston Med. and Surg. Journ., as quoted in the Lançette Français. Mars, 1835.

That the air sometimes proves fatal, by depriving the heart of its supply of arterial blood through the coronary arteries, appears to be a very visionary doctrine, and I cannot recollect any facts which give it even a semblance of truth.*

With a view of elucidating the question proposed for consideration in this chapter, the following experiments were performed.

Experiment.—The subject of this experiment was a horse about seventeen hands high, and in pretty good condition, but which was condemned to death on account of an incurable cancer of the foot. A tube, a quarter of an inch in diameter, was introduced into the left jugular vein. The man who blew, filled his chest twice, and continued to blow for a minute. He then stopped on account of the symptoms of uneasiness which the animal exhibited. In a few seconds the horse staggered and fell, and in three minutes from the commencement of the introduction of air, was quite dead. During the period he survived after falling, he made great and violent efforts to inspire, and during that time, was strongly convulsed, the convulsions commencing soon after he fell. It was computed that he lost about eight quarts of blood, which is the quantity usually taken at an ordinary venesection.

Sectio.—Air was found in every visible vein over the whole body. The chest was opened an hour and a half

* Another very questionable doctrine is that of Pigeaux, who denies that the entrance of air is the sole cause of death, and considers that much of the deleterious consequences may be attributed to the injury sustained by the small nervous branches. Surely this is absurd. Gaz. Med. 28 Mars 1833.

after death, when the lungs were seen collapsed, and in no degree emphysematous. All the cavities of the heart, but particularly the right auricle, were distended, and had a tense elastic feel. The right side was first examined. The auricle was enormously distended, and upon a small opening being made with the scalpel, frothy blood, with which this cavity seemed to be entirely filled, instantly rushed out. The greater part of the ventricle was filled with fluid and coagulated blood, but there were also some in a frothed state. The left auricle contained frothy blood, and some coagulated masses. In the left ventricle the quantity of air was just sufficient to make its existence appreciable; but there was a great quantity of blood, both fluid and coagulated in this cavity.*

Experiment.—A tube about equal in diameter to a crow quill was inserted into the right jugular vein of a rabbit. In the course of two minutes I introduced three or four full expirations. During this time the animal lay quite tranquil, and did not struggle in the least, but the breathing was difficult, and the heart's action feeble and fluttering. Just as I desisted from blowing, I observed some slight convulsive movements of the limbs, and in a few seconds more they recurred. Respiration had now ceased, and there were no more convulsions. The thorax was immediately laid open. Great venous congestion everywhere presented itself. The heart was enormously distended. Upon puncturing the right auricle and ventricle, air unmixed with blood issued forth, and in the auricle there was a good deal of

* Dr. John Reid, and Mr. William Scott were present at the performance of this experiment.

frothy blood. The froth was not nearly of so light a consistence as in the former experiment, owing probably to the blood and air not having had sufficient time to be thoroughly agitated together. The left side of the heart contained fluid blood. It is worthy of remark, that the irritability of the heart was almost extinct. Even though rapidly relieved of its load of blood and air, the contractions excited by pricking it with the knife were unusually trifling. In the horse again, the contractions of the heart continued very forcible long after it had been cut out of the body. The lungs were next examined, and were found to be quite healthy. They were collapsed, and in no degree emphysematous. In the vena cava and some of the larger abdominal veins, bubbles of air were observed, but in most of the other vessels examined, none could be detected.*

Since in both of these experiments, the structure of the lungs was in no degree broken up, we must refer the cause of death either to the heart or to the brain. Now, in both instances, the convulsions indicating an affection of the brain, appear to have been secondary results, and the immediate cause of death, the stoppage or derangement of the heart's action, in consequence of an over distension of its walls. It is probably in the agonies of death, and in those cases where the heart's action at that time becomes quickened, or, as is frequently the case, assumes an irregular or vermicular movement, that the frothing of the blood takes place. The appearance is by no means uniform, and I have seen the blood and air wholly unmixed.

The following experiment shews, that air may be thrown

* My friend Mr. Thomas R. Scott assisted me in performing this experiment.

into the jugular vein with great violence, and yet no emphysema be produced.

Experiment.—A tube was inserted in the jugular vein of a dog, and a large quantity of air introduced suddenly and with great force. The time occupied in this process was about six seconds, and at the end of this time, the vein was so distended with air, that no force employed caused any more to enter. I was just proceeding to tighten a ligature round the vessel, when the animal began to struggle, and after uttering some cries, expired in twelve seconds from the time the introduction of the air commenced.

Sectio.—The chest was immediately examined. *The lungs presented their usual appearance.* The heart was greatly distended, and from its engorged state was contracting very feebly. The right side of the heart was full of light frothy blood. The inferior *cava* contained little blood, but was much distended with air, as were to a greater or less extent most of the venous trunks of any considerable size. The coronary veins presented the same appearance as the inferior *cava.* In the veins of the hind legs there were only a few bubbles of air, but it was observed that all over the body there was great congestion of the venous system. There was no air in the left side of the heart. The obvious explanation of these phenomena is, that the air had been sent directly through the right auricle into the inferior *vena cava* and coronary veins; for its absence from the left side of the heart clearly indicates that what was found in the veins had not made the round of the circulation. From this experiment then it appears that very great force may be used without producing any em-

physema, and it may be added as a circumstance worthy of note, that there was but little frothy blood in the pulmonary artery.*

The phenomena both before and after death described as having been seen in those individuals who have died suddenly on the operating table, owing to the accidental admission of air, fully bear out the views now stated. The first case of the kind which attracted general attention, happened in Paris in 1818. It is particularly interesting and valuable, from the circumstance that the appearances detected on dissection were quite different from those expected :—the belief being that the right sac of the pleura would be found full of air.

Beauchere was removing a tumour from the right shoulder. When detaching the last adherent portion with the bistoury, a peculiar sound was suddenly heard, similar to that caused by the entrance of air through a small opening into the thorax of a living animal. It was the opinion of all present that the pleura had been wounded. The patient exclaimed, "*mon sang tombe dans mon cœur ! je suis mort!*"—he became pale, his head fell backwards, the eyes were fixed, and he could not distinguish objects. Respiration was easy but loud, and seemed to be performed chiefly by the left lung ; the movements on the right side of the chest being very

* One not acquainted with the appearance usually presented by the lungs of rabbits, might easily suppose that there was emphysema when that organ was nevertheless in its ordinary condition. For what seems to be the healthy state of the rabbit's lungs bears a very close resemblance to emphysema in the human subject. It is therefore not so satisfactory to make this experiment on a rabbit. In the above experiment I was assisted by my friends Messrs. Thomas R. Scott, and William Scott.

feeble. The pulse was extremely small, frequent, hard, and irregular. The whole body was covered with a cold sweat, and he had some convulsions. All restorative measures failed, and the patient died a quarter of an hour after the fatal cut had been given.

On examining the body eighteen hours after death, the chest was found to contain a quantity of red coloured serum. The lungs were free from all disease;—they crepitated and filled both thoracic cavities. There was no opening into the right pleura. On examining the seat of the operation, it was found that the jugular vein had been wounded. In fact, a portion of this vessel (half its calibre, and an inch in length,) had been cut out. The wound in the jugular, terminated just as it joined the subclavian vein. The superior vena cava contained no blood; its internal membrane was red. The pericardium was filled with serosity. None of the cavities of the heart contained any blood. The left side seemed to be in a natural state;—perhaps the ventricle was a little thickened. The walls of the right cavities were flabby, very thin, pale, and of a much greater calibre than those of the opposite side. The brain presented a grey appearance, and all its blood vessels of a size sufficient to be visible, were distended with air. The aorta, crural arteries, and inferior vena cava contained air mixed with blood.

An event of a similar nature to that now detailed, happened at the Hotel Dieu in Paris in 1822, when Dupuytren was removing a tumour from a girl's neck. A sound similar to that heard in the former case, led the operator to remark that had he been cutting in the neighbourhood of the air passages he would have supposed that he had made an opening into some of them. No sooner had he said this,

and at the same time given the last stroke of the knife which concluded the separation of the tumour, when the patient exclaimed, *I am dying*, was seized with a general trembling, and quickly expired.

All the usual methods resorted to for the recovery from syncope and asphyxia were tried without any success, though persevered in for several hours.

Sectio.—The body was examined twenty-four hours after death, and the right auricle was found distended with air so as to give it an elastic tension, and when an incision was made through its parietes, the air escaped in great quantity without any admixture of blood; it nevertheless contained a small quantity of uncoagulated blood. The other cavities of the heart (which were healthy,) the arteries and veins throughout the body, and the membranes of the brain, contained fluid blood mixed with air. The lungs were red, pliable, crepitant, elastic, and perfectly healthy. There was no wound in the trachea. The serous membranes of the brain were thin and transparent, without serosity and without injection. Its tissue was firm, uninjected, and with the colours well marked. Red spots were observed on the stomach, some of them evidently owing to injection of the capillaries. The muscles were firm and red.

In neither of these cases are there any facts of importance to support the hypothesis of Bichat. The presence of air in the vessels of the brain sinks into insignificance, when we discover that it is also found in every minute artery and vein all over the body. The existence of emphysema of the lungs in Beauchere's case, may fairly be considered as purely accidental. In the operation cases detailed, as well as others of a similar nature on record, it was in all probability produced by

the artificial respiration had recourse to. It is almost impossible to perform this process, without to a greater or less extent breaking up the air cells. Both in my own hands and in others more expert, I have uniformly seen some amount of emphysema produced when endeavours were made to recover animals by means of artificial respiration. Perhaps it is from serious injury being done to the lungs, that so few infants resuscitated by this method survive more than a few days; and there is much reason to fear, that the rude apparatus frequently employed by unskilful persons for the recovery of those apparently drowned, is the cause of so little advantage being derived from artificial respiration in such cases.

The following case may be classed along with those of Beauchere and Dupuytren already described. When Mr. Barlow of Blackburn, Lancashire, was removing a tumour from the side of the neck of a delicate lady, and was "proceeding to dissect aside the skin to get at the basis of the tumour, a sudden and unexpected hissing gurgling noise rushed obviously from a large divided empty vein, and the patient expired instantly, without either sigh, groan, or struggle, and every effort to restore animation was fruitless. This unexpected event," Mr. Barlow goes on to remark, "was truly appalling to all present, for scarcely an ounce of blood was lost on the occasion, and her death was then wholly attributed to a state of debility and syncope, which opinion I acknowledge remained unchanged till I accidentally met with the case of Dupuytren."*

A fatal case of a similar nature occurred to Dr. Warren of Harward University, when removing a cancerous mam-

* Med. Chirurg. Trans., vol. xvi., p. 29.

ma. The vein through which the air entered was the subscapular. As the phenomena preceding death were quite similar to those already described, and as there was no *post mortem* examination, a detail of the case would throw no additional light on the subject, and is consequently omitted.*

There are various circumstances which render it possible that in some instances in which women die unexpectedly after parturition, and when all seems going on well, death is owing to air entering the circulation by means of the open mouths of the veins communicating with the uterine sinuses.† These orifices, immediately after the separation of the decidua, are very large. They have been made the subject of investigation by many modern as well as old anatomists and obstetricians, and upon the whole the various descriptions correspond. Burton says, that the uterine sinuses "in the ninth month of gravitation are so large as to admit the end of the biggest finger; and their orifices that open into the cavity of the womb, will at the same time admit the end of the little finger."‡

Now the uterus not unfrequently contracts and expands alternately with considerable energy after the expulsion of the fœtus, and it is quite reasonable to suppose that air may sometimes be sucked into the gaping mouths of the uterine

* Medical Gazette, vol. xii., p. 270.—Case of Nancy Bunker.

† Olivier, in the article *Air* in the Dict. de Med., (2nd edit.) asks whether those cases of unexpected death after parturition may not be explained in this way.

‡ New System of Midwifery, p. 19. Ed. 1751. Dr. R. Lee claims the discovery of these openings. The above quotation shews that he is in error in doing so. *Vide* Med. Gaz., vol. xii., p. 202, where priority of discovery is discussed.

vessels, in sufficient quantity to prove fatal to a female exhausted with the fatigues of labour.

Le Gallois mentions three female animals, upon which he was making experiments with a view of observing the effects of abstinence and loss of blood, in which sudden death took place from air entering the circulation by the uterine veins.*

Baudelocque† states, that in examining the bodies of patients who had died of uterine hæmorrhagy in the hospital of *La Maternité*, he constantly found a gaseous substance in the arteries. This he assigns (apparently without any reason) as the cause of the convulsions which precede death. He states that he has no doubt but that the gas is spontaneously generated. This opinion may or may not be correct, for it is at least possible that the air may be admitted from without, since the bleeding depends upon the imperfect closing of these sinuses; and as in cases of uterine hæmorrhagy after labour, convulsive contraction and dilatation of the uterus is not uncommon, the possibility of death being occasioned by the air drawn in by this sucking power is at least entitled to consideration. It must be admitted, however, that with the scanty light which the records of pathology are yet able to throw upon this point, it would be rash to give any decided opinion upon the subject.

In a case recorded by Leclerc (and which occurred in the practice of Dubois and Boyer), we can hardly conceive that the air was drawn in by the process above suggested. Madame B——, a delicate lady, who had for some time suffered from a dull pain in the left inguinal region, was

* Ann. Hebdom. de Med., vol. iii., p. 183. Paris, 1829.

† Traite des Hemor. Internes de l'Uterus, p. 66. Bruxelles, 1832.

suddenly seized with hæmorrhagy from one of the uterine vessels, and died in the course of three hours. Upon examination of the body, various morbid appearances were noticed; but what particularly demands attention is, that there was no blood in the heart, that the inferior *vena cava* contained air alone, and that the peritoneum was in some places emphysematous.*

There is no mention made as to the interval which elapsed between death and the examination, nor is it stated at what season of the year the event took place; so that it does not appear with what degree of probability the presence of air in the blood-vessels may be explained by supposing that decomposition of the blood had taken place. It must also be remembered, that in death from hæmorrhagy, it is not unusual to find air in the veins. Mery states, that if the blood of an animal be drained out from an opening in the inferior vena cava, the veins fill with air in proportion as they empty of blood, and that the air comes from the smaller into the larger veins.† Nysten says that this is by no means a constant result, and that it depends upon the size of the opening made in the vessel.‡ I have repeated Mery's experiment, but found no air at all in the circulation, though the aperture in the vein was large.

Another question suggested by the above considerations is, whether air generated within the body during life is not sometimes the immediate cause of death; but this topic is not here discussed, because it appears that it may be more naturally attended to afterwards.

* Archives Gen. de Med., xviii., p. 281.

† Mem. de l'Acad. des Sciences, an. 1707. p. 167.

‡ Nysten, op. cit. p. 4.

In conclusion then, it may be stated as clearly established, that when a quantity of air, by entering the circulation, proves suddenly fatal, the immediate cause of the arrestment of the vital functions is the inability of the right side of the heart to contract and expel its elastic contents; and therefore, all the phenomena which follow are consequences of this first cause.*

* Accidents in consequence of the entrance of air into the circulation, have occurred to the following operators: Sir A. Cooper; Mr. Barlow of Lancashire; Mr. Simmonds of Manchester; Dupuytren, Beauchere, Clemot, and Roux, of Paris; Drs. Mott and Stevens of New York; Dr. Warren of Harward, U. S.; Dr. Castara of Lunéville; Delpech of Montpellier; Graefe of Berlin; Goullard of Lyons; and doubtless to many others, by whom the cases have not been put on record. Indeed it is surprising, that so many of these accidents should have been published, during the comparatively short period that has elapsed, since Dupuytren first turned the attention of the medical world to the subject.

CHAPTER II.

CIRCUMSTANCES WHICH MODIFY THE EFFECTS. OBSERVATIONS ON CASES IN WHICH DEATH DID NOT TAKE PLACE, OR WAS A SECONDARY RESULT.

It has already been stated, that very considerable quantities of air may be introduced into the circulation without producing death. The concurrent testimony of a variety of experimenters establishes this beyond the possibility of doubt. Sometimes the patient to whom the accident happens, or the animal experimented upon, suffers only transient inconvenience, or makes a complete recovery, and in other instances death ensues so late as some days after the admission of the air. Two very interesting subjects of investigation are thus presented to our notice. In the first place, what are those circumstances which thus modify the result? And then, what is the nature of the modifications which occur under these varying circumstances?

First, then, let us attend to the different modifying causes. These appear chiefly to be referable to three heads: 1*st*, *the quantity of air admitted*;—2*nd*, *the rapidity of its admission*;—and, 3*rd*, *the situation of the orifice through which it enters*. For the sake of perspicuity, each of these points will be separately illustrated.

1*st*, That *the result is modified to a very great extent by the quantity of air admitted*, it is unnecessary to insist upon at any length. The experiments of Nysten, Magendie, Wing, and others, clearly shew that it is only when introduced in considerable quantity that there is a fatal issue. This I have satisfied myself of by repeated experiments. The same fact has also been stated by Dr. Blundel, in his memoir on the transfusion of blood. It is probable that when slowly introduced, the oxygen is either in whole or in part absorbed, and the volume of the elastic fluid thus materially diminished. That such absorption does really take place there can be no doubt, for the experiments of Dr. Christison distinctly prove that the oxygenation of the blood is a purely chemical process, and that even out of the body venous blood absorbs a large quantity of oxygen, and changes its purple for a florid hue.*

Nysten infers from various experiments that some of the injected gas may be thrown off by the lungs.

It appears, however, that a large quantity of air may enter the heart, and nevertheless no such phenomena be manifested, as took place in those cases and experiments already detailed. This statement is founded upon the following

Experiment. Six or seven full expirations were injected through a small tube into the jugular veins of two dogs. A little difficulty of breathing ensued, but this soon passed away. At the end of half an hour the animals were killed, having up to that time seemed pretty lively, and exhibited

† Edinb. Med. and Surg. Journ. Jan. 1831.

almost no symptoms of uneasiness. Upon examining the chest immediately after death, the lungs were in both instances found collapsed, and devoid of emphysema. The heart particularly in one instance was greatly distended with air, and had an elastic feel. In both instances, when the scalpel was thrust into each of the cavities of the heart, a little air unmingled with blood rushed out with a whizzing noise. Not the slightest trace of frothing could be detected—a circumstance which by the way, it may be remarked, tends to corroborate the notion formerly suggested, that the frothing of the blood is caused by the irregular motions of the heart which sometimes immediately precede or follow death.*

In the experiments described in the first chapter, almost the whole calibre of the vein was occupied with the tube, and death ensued in a very few minutes, whereas in the cases of the two dogs just detailed, a good deal of blood was allowed to flow down the vessel along with the air, and hence it was, I apprehend, that the baneful effects were so little apparent.

2*d*, It may be stated as a general conclusion, that *the greater the rapidity with which the air is introduced, and the greater the diameter of the tube through which it passes, so much the more sudden and deleterious is the result.* This appears obvious from various statements already made, and it is therefore unnecessary in this place to supply additional illustrations.

In those cases of operation in which a fatal termination almost immediately ensued, it seems evident, that owing to

* My assistants in performing this experiment were Drs. J. Y. Simpson, and J. H. Pollexfen, and Mr. William Scott.

a thickening of the coats of the vein, or from other causes afterwards to be stated, the vessels were unable to collapse; and if thus kept in a patulous state, it is easy to conceive how rapidly the right side of the heart would become distended with air; for it is clear, that when a vessel in such a state is cut across, air, and air only, would pass down it.

The effect produced *when great force is used in blowing*, is well illustrated by the experiment upon a dog, mentioned in the first chapter, (p. 13.) In that case, the right side of the heart was suddenly and violently distended with air, and death took place with the greatest conceivable rapidity.

It was probably owing to the great force used, that the following experiment proved fatal; for certainly the small quantity of air injected was not of itself sufficient to produce the result. M. Bassereaux, when assisting Dr. Bretonneaux to inject pus into the jugular veins of dogs, happened upon one occasion, imperfectly to fill the syringe. The canula was introduced into the vein, and the piston pressed down; but before the liquid had entered the circulation, (and dissection shewed that not a drop of pus had been injected) both gentlemen heard a distinct "*gargouillement.*" The experiment was instantly stopped, and *in half a minute the animal fell down* on its side, in strong convulsions. The respiration was laboured and stertorous, and *death took place in two minutes.* Upon dissection, *only a few bubbles of air were found in the right auricle*, which was almost entirely gorged with blood. The principal object of mentioning this case is, that unless explained in some such way as has now been done, it might possibly be adduced in favour of the doctrine of Bichat.

3*d*, The only other modifying circumstance proposed for

consideration, is *the situation of the orifice through which the air enters.*

Magendie made the curious discovery, that when air is injected into one of the branches of the *Vena portæ*, no inconvenience seems to result from the operation. This must obviously depend upon some change which the air undergoes in its passage through the portal circulation. It is either absorbed, or so intimately mixed with the blood, as to be rendered incapable of causing any impediment to the circulation.

Experiment. I threw a quantity of air into one of the mesenteric veins of a rabbit, and in eight minutes afterwards killed the animal. The liver was in a state of almost complete anæmia, and upon slicing it, minute bubbles of air appeared at every point on the incised surfaces. There was no air apparent in the heart, nor in any part of the body, except the liver.*

Having thus very briefly considered the principal circumstances which modify the effects resulting from the admission of air into the circulation, it still remains for us to attend to the precise nature of the modifications presented under these varying circumstances.

We have seen that quantity modifies the result to a very great extent; but to what extent I am unable to state, as I have killed one animal with much less than was required to destroy another, apparently similar in strength and size. As a vast number of experiments would have been necessary, before any thing like a satisfactory average result

* Assistants in this experiment—Mr. Thomas R. Scott, and Mr. William Scott.

could be obtained, I was not long in perceiving the necessity of (in the meantime at least) abandoning this part of the investigation. But this was done with less reluctance, as the point did not appear to be of very essential importance, and seemed to be one which, whatever trouble might be bestowed upon it, could after all only be elucidated to a certain extent.

Very violent effects may be produced by the injection of air into a vein, and yet the animal operated upon may spontaneously recover. For example, Dr. Wing threw by degrees a considerable quantity into the jugular vein of a sheep. At each stroke of the piston of the syringe, a gurgling sound was heard in the heart, there was slight difficulty in breathing, and strong convulsions. The experiment occupied ten minutes. When the animal was released at the end of this time, he manifested a desire to eat, and mixed with the rest of the flock.* Similar experiments have been previously described by Nysten and others.

Those cases which prove fatal after the lapse of some days, afford a most interesting and important subject of inquiry. In some instances death is owing, as Nysten's experiments prove, to an affection of the lungs. This able experimenter states, that when the air is not in sufficiently large quantity to put a stop to the vital functions, by arresting the contractions of the right side of the heart, it is forced into the minute ramifications of the pulmonary artery, thus producing such obstruction as causes bronchitis, which may terminate in death ; and it appears that this event sometimes happens so late as the third or fourth day. In a case belonging to this class, the following are the *post mortem*

* Boston Med. and Surg. Journ., as quoted in Lançette Française, Mai 1835.

appearances described, the examination having been made two hours after death. The pleuræ presented their natural appearance, but the lungs were of a greyish colour, mixed with brown spots, somewhat gorged with blood, and much distended with frothy mucus. There was not a single bubble of air in the heart, nor in any of the blood vessels. Both ventricles contained blood, and in these cavities there were small yellow semi-transparent concretions. Nysten observed a similar state of the lungs in repeated experiments of the same nature.*

I was anxious to verify these experiments of Nysten, but was never lucky enough to obtain a case at all resembling those which he details as perishing from secondary thoracic symptoms, though I had several instances of spontaneous restoration to health, after the injection of a large quantity of air. There was one rabbit in which I fully anticipated something such as he describes, but complete and speedy recovery took place. This is an account of the

Experiment.—A large quantity of air was injected into the jugular vein. Very violent effects were produced, so violent indeed, that the animal seemed for twenty minutes to be in a moribund, or at least in a very critical state. To our astonishment, however, it gradually came round, and in about an hour the respiration, which was at first very laboured, became tolerably natural, and the rabbit was soon little out of sorts. In a few hours afterwards the breathing, as far as I could judge, was quite natural, and the animal ate food with avidity. I kept it for sixteen days, and never observed anything wrong, excepting an abscess which formed in the seat of the operation.

* Nysten, op. cit. p. 36, &c.

Upon dissection, immediately after killing it, the lungs were found to be perfectly healthy, and there was no air in any of the blood vessels.*

It is the opinion of some, that death may take place after the lapse of some days from the time the air has entered the vessels, and yet be attended with all the striking phenomena usually presented when the fatal event is an immediate consequence. I am not aware of any facts which at all justify such a supposition, but since the notion is entertained by some, it is proper to mention it in this place.

The following case is interesting, though unfortunately it does not throw any very positive light upon this part of the subject, since, by assuming either view as correct, the phenomena may be satisfactorily explained. It is as much, therefore, with a view of shewing that although the most formidable symptoms have been manifested, and immediate death seems almost inevitable, the patient may notwithstanding speedily rally; thus pressing upon our attention the important fact, that if the heart be in any way sufficiently disencumbered of the air, it may regain its natural action, and the circulation, after having been all at once violently disordered, and almost arrested, may in a few minutes go on as before the accident. This points out the important practical bearing of our inquiries, and holds out a good ground of hope that some useful rules may be suggested, by an attentive consideration of this branch of the subject.

But to proceed.—M. Roux, when removing a tumour situated on the cellular sheath surrounding the common carotid artery, jugular vein, and pneumogastric nerve,

* I was assisted in this experiment by Mr. T. R. Scott, and Mr. W. Scott.

made an opening into the jugular vein. Upon inspection after death, it was found that the vein had been wounded transversely, and that on account of the morbid thickening of its walls, the inferior aperture was gaping. At the moment the operator lifted up the tumour to enable him to dissect it out, a sort of whistling noise was heard, like that produced by the entrance of air into the empty receiver of an air pump. The patient uttered a plaintive cry, and became greatly agitated—the contractions of the heart were hurried, the pulse was weak, respiration long and laboured, and at length, after one protracted inspiration, followed by a short and hasty expiration, symptoms of approaching death were manifested. By preventing the admission of any more air, and the employment of frictions, and stimulants to the nostrils, and dashing water on the face, the circulation and respiration were restored. The dissection was discontinued, and the tumour enclosed in a double ligature. All went on well till the seventh day, but on that morning the patient suffered from oppression, difficulty of speech, then from coma, and died during the night.

Sectio. The eighth pair of nerves were uninjured. Both lungs were slightly congested, and emphysematous spots were observed under the pulmonary pleura. The cavities of the heart were empty. On puncturing the abdominal and thoracic aorta in different places, a great many bubbles of air escaped, mixed with bloody serum, and the same could be observed, but in less quantity, in the iliac arteries.* There was no air in the vessels of the brain.

The narrator of this case asks whether the non-occurrence

* Abridged from the Dublin Journ. of Med. and Chem. Science, vol. iv. p. 475. Vide also *Puyderat's* account of this case in the Journ. Univ. et Hebdom. Tome xi. p. 165.

of death till the seventh day was owing to the small quantity of air admitted during the operation, or to a fresh quantity having got in immediately before death, owing to the inferior opening of the vessel still remaining gaping on the surface of the wound. He conceives that the frothy serum found in the bronchial cells, and the emphysematous spots noticed under the pulmonary pleura, render the latter supposition plausible, but even granting that the emphysema was produced by the air which entered the wounded vein, it is just as likely to have been caused at the operation as afterwards, and as for the frothy serum, it is by no means an unusual *post mortem* appearance in most diseases. The absence of the laboured breathing and other characteristic phenomena described as ushering in death, from the admission of air into the veins, throws a good deal of obscurity over the nature of the case, and appears to render it highly probable that there were some causes operating which do not appear in the narrative. Might not the oppression and coma depend on something quite different from air in the circulation, such as phlebitis, or inflammation of some important organ? Be that as it may, the air might have entered, owing to the slipping of the bandages, immediately before, or to a certain extent during the death struggles.

It appears, at all events, that although sudden death does not follow the admission of air, and immediate danger be averted, there are disasters still to be dreaded, the most important of which are inflammation of the lungs, and the admission of more air, to which may perhaps also be added the danger of phlebitis, in consequence of the injury done to the vein in the operation, or owing to the violence of the measures adopted to prevent immediate death.

CHAPTER III.

ON THE CAUSE OF THE ENTRANCE OF AIR INTO VEINS DIVIDED DURING OPERATIONS; WITH SOME CONSIDERATIONS ON THE MEANS MOST LIKELY TO AVERT DEATH IN SUCH CASES.

The only condition absolutely necessary for the admission of air during an operation is, that the vein be kept in a patulous state, for when in this condition, the movements of the chest in respiration (assisted perhaps by the tendency in the right auricle to form a vacuum during its diastole) are sufficient to cause the air to enter. This may at least be inferred from Sir David Barry's experiments. He shewed, that during inspiration a suction influence is exerted upon the blood in the veins entering the chest. Now when this suction is exerted upon the contents of a wounded vein, *incapable of collapsing from disease of its coats or any other cause*, these contents, whatever physical properties they present, must be under the influence of the same law which was pointed out by Sir David Barry with regard to the blood in unopened vessels. Should the vein be completely severed, it is evident that air, and air only, will pass down to the heart; but if, on the other hand, it be merely wounded, there will be a mixture of blood and air.

The patulous state of the vein may depend on two causes :—1*st*, The vessel may be gaping in consequence of a rigidity of the coats caused by disease; or, 2*nd*, It may be kept open by the constrained position of the patient, or the manipulations of the operator and his assistants. M. Berard, I am aware, ascribes the phenomenon chiefly to the anatomical peculiarities of the vessels, independent of disease.* He has shewn that the large veins near the heart have fasciæ closely adherent to their coats, and that these fasciæ are attached to bones. This connexion, he believes, is of such a nature as to prevent the collapse of the veins. One decided objection to this explanation is, that the entrance of air by no means always follows a wound of these vessels; and seeing that the admission of air is not a necessary consequence of a wound of a vein provided with such a fascia, how can it be established that this fascia is in any one instance the cause of the entrance of air? The anatomical facts, then, pointed out by Berard cannot be regarded as at all explaining why veins sometimes remain uncollapsed, in spite of the suction power of the heart and chest, and the influence of atmospheric pressure; but they may, however, be viewed as to a certain extent favouring the occurrence of the phenomenon.

It is not, however, only by the great vessels in the neck that air has been known to get in. Air entered the saphena of a patient upon whom Dupuytren was operating; and when Clemot was removing a tumour from the breast of a female, it entered a divided vein, and in consequence of this, the woman died a few hours after the operation. Upon dissection, the right side of the heart was ascertained

* Archives Génerales de Méd. Juin., 1836.

to be distended with air.* "In an attempt which I made," says Dr. Mott, "to remove the parotid gland in an enlarged and schirrous state, the facial vein where it passes over the base of the lower jaw was opened, in dissecting the integuments from the tumour in the early stage of the operation, before a single artery was tied. At the instant this vessel was opened, the attention of all present was arrested by the gurgling sound of air passing into some small opening. The breathing of the patient immediately became difficult and laborious. The heart beat violently and irregularly, his features were distorted, convulsions of the whole body soon followed to so great an extent, as to make it impossible to keep him on the table. He lay upon the floor in this condition for near half an hour, as all supposed *in articulo mortis*.

"As the convulsions gradually left him, his mouth was permanently distorted, and complete hemiplegia was found to have ensued; an hour or more elapsed before he could articulate, and it was nearly a whole day before he recovered the use of his arm and leg."†

In most cases on record, we may infer, from the descriptions given, that there was a diseased state of the coats of the

* Lançette Française, 30th Nov. 1830. Clemot there details the particulars of two other accidents of a similar nature, which occurred in his own practice. In one case he was dissecting out a tumour from the axilla, and in the other tying the subclavian artery. Goullard of Lyons, when removing indurated glands from the axilla, wounded the axillary vein. Only a small quantity of blood was lost; but in an instant the patient became pale, the muscles of the face were convulsed, hiccup came on, which in a few minutes was followed by death. There was no *post mortem* examination. Duplat Gaz. Méd., Dec. 1833.

† Med. Chirurg. Journ. Lond. vol. xvi. p. 33.

vessels; but at the same time, a peculiar and constrained position of the parts might, as has already been stated, keep a vein in such a state as to allow of a large quantity of air being sucked into it. Such is the explanation which must be given of the appearances observed in the case of a student who committed suicide in this city some months ago, by cutting his throat. There was almost no blood lost; and upon examination, the heart was found to contain air in all its cavities. I am informed there was no thickened condition of the veins of the neck observed.

In the transfusion of blood, air may be, and doubtless often has been injected into a vein; but if the operation is performed with very ordinary dexterity, it is difficult to imagine how a quantity sufficient to produce any disastrous consequences could be thrown in. Dr. Blundel, who has carefully examined this point, says, that "it seems probable that the entrance of a few drachms of air into the vessels would be attended with considerable distress, and even danger; but it must be recollected, that if the operation be carefully performed by a competent person with a proper instrument, there can be no risk lest air should enter the vessels in large quantities; and the probability is, that a bubble or two of air would occasion little if any inconvenience."*

The interest and importance of a physiological investigation are greatly enhanced, when we enter upon it with a hope of being able to deduce useful rules of practice from our observations, and it is the belief of the author that his subject is possessed of this attraction. It has appeared,

* Ashwell's Practical Treatise on Parturition. Appendix by Dr. Blundel, p. 538. London, 1828.

from what has already been advanced, that the deleterious effects resulting from the entrance of air during operations is purely mechanical, and that the death of the patient depends simply upon the contractions of the right side of the heart being arrested, or greatly impeded, in consequence of the presence of that elastic fluid. Hence it is naturally suggested, that the means most likely to afford safety to the patient will consist in relieving the heart with the greatest possible expedition—an inference, it may be remarked, which points out the practical importance of studying the order in which the vital functions become arrested.

We are also strengthened in the hope, of being frequently able in this way to save the patient, by a knowledge of the astonishing advantages which result from opening the jugular vein in certain cases of poisoning, in which the deleterious agent produces a sudden but merely transient arrestment of the contractions of the heart, and where death seems to result from this state being rendered permanent, in consequence of the distention which has taken place during the period of temporary inaction. We generally find that in such cases, by timeously relieving the congestion of the heart, its contractions are in the course of a few seconds renewed, and speedily go on with nearly their usual regularity; but if this be not done, the animal generally dies very quickly, the circulation being greatly impeded, or wholly arrested by the mechanical distention of the heart with blood. The intervention of the valve does not prevent a reflux current, as might be supposed, so that this important principle admits of easy application, both in cases of engorgement with blood, as well as in those in which air is the distending agent.

Haller, both in his Physiology, and in his treatise on the Movement of the Blood, distinctly states that the right side of the heart can be emptied by opening the jugular vein. He believed this to be entirely owing to derivation of blood, and as in no way dependent upon the contractions of the heart. This view was also adopted by Spallanzani, who repeated the experiments of Haller. The flow of blood from vessels opened at a distance from the centre of the circulation, certainly appears to depend entirely upon derivation; but when large veins near the heart are opened, there seems also to be another cause in operation. This was first stated by my friend Dr. John Reid, in a paper which he published in the 127th number of the Edinburgh Medical and Surgical Journal. He conceives that the unloading of the heart, when the jugular vein is cut into, depends upon two causes; one of them being the derivation of Haller, and the other the contractions of the right side of the heart. In cases of extreme engorgement, the latter cause can only come into operation, as a consequence of the former.

"At each contraction," Dr. Reid remarks, "the heart attempts to force a certain quantity of blood along the vessels connected with it, and as there is no *vis a tergo* to prevent the action of the heart moving the blood along the veins in its immediate neighbourhood, a certain quantity is forced out through the opening in the jugular." Of the accuracy of this I am perfectly satisfied, having witnessed the phenomenon in the experiments detailed by Dr. Reid, and also in the cases of different animals which I have since killed in various ways.

I have endeavoured by a detail of experiments to show the advantage resulting from a copious depletion by the ju-

gular vein, in cases of poisoning with Creosote.* I have since extended the inquiry to other poisons, and in particular have made farther observations for the purpose of elucidating this point more fully with regard to Creosote and Prussic acid—substances which in large doses unquestionably prove fatal, by producing a sudden arrestment or derangement of the movements of the heart.

Since the cause of death, both in poisoning with these substances, and from the entrance of a large quantity of air into the right side of the heart is the same, viz. the inability of the heart to overcome the distention, it does not seem inappropriate to detail the following

Experiment, which illustrates most beautifully the beneficial effects of copious depletion, when a poisonous dose of Prussic acid has been administered. A free opening was made in the jugular vein of an ordinary sized pointer dog, and hemorrhage prevented by means of pressure. A dose of Prussic acid was then administered, of such strength as to contain about a drop of the real acid. The animal became almost immediately affected, uttered some faint cries, in twenty seconds fell down and lay for a few seconds motionless on the floor. He then began to struggle as if in the agonies of death ; but the vein now broke out, and the blood flowed in a rapid and copious stream. Immediately the dog shewed signs of returning vigour. He raised his head, then in a few seconds looked around him, and his eyes, which were formerly dim and suffused, regained their natural lustre. From this time he rapidly recovered, and be-

* Treatise on Creosote, pp. 84, 85, and 92. Edinburgh, 1836.

gan to lick up his own blood. At the end of an hour he did not seem much out of sorts, and was then killed, the experiment being regarded as perfectly satisfactory.*

That it really was so, I have not the slightest doubt. I have seen at least fifty or sixty dogs killed outright with Prussic acid—with doses often smaller, but seldom larger, than a drop of the real acid. Much of this slaughter was also witnessed, (about eighteen months ago,) at the police office of this city, by my friends Dr. J. Reid, Dr. J. Y. Simpson, and Mr. Skae, as well as by various others. Never did we there see such a recovery take place as that which I have now described, and it was only strong and powerful animals that survived the administration of the poison more than a very few minutes.

Experiments similar to the above were made with Creosote, and the results were almost identical with those observed when Prussic acid was employed.†

In conducting this investigation, it was found essential to the success of the operation that the blood should be very speedily and copiously abstracted; and this remark is equally applicable to the relief of the heart from air—that

* In the performance of this remarkable experiment, I had the assistance of my friends, Dr. Pollexfen, and Mr. William Scott.

† There are cases of blows on the head, (as is stated by Dr. J. Reid, in the paper already quoted,) in which the contractions of the heart are not renewed by unloading its right side. It must be borne in mind, however, that in this class of cases many anomalies present themselves, depending apparently, to a certain extent, upon the degree of shock sustained by the nervous system; but it is to be explained more fully, I think, by reference to a fact which must strike every one who performs experiments upon animals,—that the persistence of the contractility of the heart in individuals belonging to the same species, (and killed in exactly the same way,) varies very much in duration.

is, it must be done immediately and thoroughly. Nysten says, that he recovered two dogs from a moribund condition, by forcing the air out of the heart, through an opening in the jugular vein, by means of pressure on the thorax. This is certainly a very clumsy mode of proceeding, and I should think, even in dogs, not always likely to succeed. At all events, in the human subject, such a method could be of little or no avail. The recommendation here given, (which is also that of Magendie,) is certainly that which the operator ought, if possible, to follow when the untoward accidents occur, of which frequent mention has already been made. Magendie recommends the air to be drawn from the heart by applying the mouth to the divided vessel, or by pumping it out with a syringe, if that instrument should happen to be within reach.*

It is evident that the surgeon ought not, even for a few seconds, to delay his attempts to relieve the heart; and that, consequently, in most cases, he will, if he is anxious to proceed with the necessary expedition, have recourse to sucking with his mouth.

Though convinced of the advantage which results, in the majority of cases, from the removal of the air from the heart, I must admit that in a few instances, my attempts to recover animals in this way proved abortive. This ought, probably, to be attributed to too large a quantity of air having been introduced, or to some other accidental circumstance, producing a state beyond that of imminent danger, from which it was possible to relieve the animal. In spite of these unsuccessful efforts at resuscitation, I can confidently state, as a fair deduction from experiments, that

* Leçons de la vie, p. 60. A Paris, 1836.

in general, the method recommended, if promptly had recourse to, and judiciously conducted, will prove successful.

I think the experiment more generally succeeds when, along with the air, a considerable quantity of blood is evacuated. In support of this opinion, the following case is subjoined: When Bouley Junior, veterinary surgeon at Paris, was bleeding a horse for pneumonia, having ceased to compress the vein, he heard a peculiar sound, which, however, did not particularly attract his attention, as he had on former occasions remarked a similar occurrence. The operation was concluded, and the animal sent back to the stable, where it was immediately seized with general trembling. Respiration became laboured and plaintive, the pulse small, irregular, and very quick; and then we are told, that groaning deeply, he fell down as if struck by a thunder bolt. For sometime Bouley was unable to account for these symptoms; but upon recollecting the sound which was heard when he relinquished his pressure of the vein, he concluded that it might be owing to the entrance of air. Under this impression, the vein was caused to bleed afresh. As the blood flowed the animal revived; and in half an hour after the accident, he was restored to the state in which he was prior to the operation, and in three days resumed his usual work. Magendie states, that an analogous case happened to Girard at the veterinary school of Alfort.*

The advantage which resulted from the loss of blood in this case is very obvious; and may not recovery in the following instance be traced to a similar cause? When Mr. Simmonds was removing a large tumour from the left

* Journal de Physiol. Tome i. p. 197.

side of the neck of a woman in the Manchester Infirmary, in 1791, he divided the internal jugular vein. "The torrent of blood," he says, "pouring out from so large a cavity, and the noise occasioned by the rushing in of air, added to other appearances, formed a picture more frightful than I ever beheld." The patient recovered; and there is nothing said about the injurious consequences of the admission of air; from which we may presume, that none were apparent. It is merely stated, that the patient experienced no morbid affection of the head from the obliteration of the vessel.*

It naturally occurs, when reflecting upon the practical inference to be drawn from these cases, that the advantage to be derived from the abstraction of blood from the vessel which has been divided, may be prevented, or that even greater danger may be incurred, by hazarding the admission of an additional quantity of air into the right chambers of the heart. If the vessel is gaping, owing to disease of its coats, perhaps the safest plan would be to open the largest healthy vein in the neck which may be within reach; for from what has already been stated, the chance of saving the patient depends almost entirely upon the speedy and effectual unloading of the heart. Should the air have gained access, merely from the temporary gaping of the vessel, occasioned by the position of the patient during the operation, there can then be no objection, not only to sucking the air out by it, but also to giving the additional relief to the heart, which would be afforded by the derivation of blood, and the contractions of the auricle.

* Medical Facts and Observations, vol. viii. p. 23.

If the state of the parts render it necessary immediately to apply pressure to the wounded vein, and should it be impossible or inexpedient to attempt relief, by opening any of the great vessels near the heart, the next best thing which can be done, is to relieve the circulation by some less direct method, which may be readily accomplished either by venesection at the bend of the elbow, or by opening the temporal artery. Dr. Warren, of Harvard University, has published a case in which there is every reason to believe that the patient was saved by the latter operation. When this gentleman was removing a cancerous tumour from the left side of the face and neck, in a case in which all the neighbouring tissues were involved in the disease, a very distinct sound was heard resembling the passage of air through water. The patient became faint, his countenance livid, respiration stertorous, and convulsions were observed. The wounded vessel (which was a small vein running across the neck) through which the air had rushed, was immediately compressed, and the temporal artery opened, when the blood issued forth in abundance. During the first twenty minutes there was a very marked abatement of the alarming symptoms. He continued, however, in a state of insensibility, for two hours and ten minutes longer, when he awoke, as if from sleep, and on the following morning was in his usual state, with the exception of some soreness over the thorax, and a headache. The operation was afterwards completed; and when the wound had nearly healed, the patient was dismissed at his own request.* The time during which he was in the hospital after the accident,

* Medical Gazette, vol. xii. p. 269, where Dr. Warren's paper from the American Journal of Medical Science is given.

is not stated; but it must have been considerable, since it appears that seven days intervened between the first and second operations.

Artificial respiration, frictions, the application of stimuli to the nostrils, and especially the cold effusion, may in certain cases be used as subsidiary means; but they are certainly not entitled to that primary importance which is generally assigned to them by those who have written on this subject. No time ought to be trifled in blowing and rubbing, but the root of the evil should be at once laid siege to.

Warren has very strange notions regarding the treatment to be adopted. After recommending both the external and internal use of ammonia, dashing cold water on the face, the introduction of a tube into the glottis, or through an aperture between the thyroid and cricoid cartilages, for the purpose of carrying on artificial respiration, and so on, he proceeds to say—"an attempt to pump the imbibed air from the heart from the internal jugular vein, by means of a syringe, is an operation that cannot be recommended, since it appears more likely to allow the entrance of a farther quantity of air, than to abstract that already admitted." In reply to this, it is sufficient to say, that the heart can be much more readily relieved by a method different from that which he condemns. But he goes on to make a most extraordinary suggestion in the next sentence, where it is said, "A proposal which might at first sight seem scarcely more plausible than that mentioned, might be made with some hope of advantage. The introduction of a liquid into the veins, has been often attended by the revival of the patient in cases of cholera, though rarely with ultimate success. In this accident, the vital powers not having received that

lesion which is the result of an exhausting disease, it may be hoped that a successful revival might sometimes be effected by means of the injection of the saline solution into the veins."* There can be little doubt, but that the injection of a fluid into the veins would increase and not diminish the danger; but what analogy exists between cholera patients, and the class of cases at present under consideration, it is not easy to divine. Is a man, writing in any work, but especially in one which is to be extensively circulated among the junior members of the profession, justified in making such a recommendation, without previously putting it to the test of experiment upon the inferior animals, or at least having some plausible theoretical argument to adduce in its support?

The measures which the surgeon ought to adopt with a view of guarding against the admission of air during an operation, are very obvious. When operating on parts extensively diseased, or when cutting in the vicinity of the large veins in the neck, he must pay special attention to the position of the patient, and when obliged to divide a large vein, he ought not to be unprepared for the accident taking place. With a view of averting it, he ought, before making the hazardous incision, to request the patient to take a full inspiration, so that the vessel may be divided during expiration.

Should it happen, however, that in spite of every precaution, a dangerous quantity of air gain access, not an instant must be lost in adopting the measures formerly pointed out, as the most likely to save the life of the patient.

* Cyclop. of Pract. Med. and Surg., Article, *Air*, p. 266. Philadelphia, 1834.

CHAPTER IV.

REMARKS UPON THE GENERATION OF AIR IN THE LIVING BODY, ESPECIALLY IN THE BLOOD VESSELS, WITH OBSERVATIONS ON THE CONSEQUENCES WHICH MAY RESULT FROM ITS PRESENCE THERE.

PRETERNATURAL accumulations of air take place in almost every part of the body. They have been noticed in situations where air ought naturally to be found, as well as in those where it ought not to exist—in organs which communicate, and in those which do not communicate with the external air. It is known to accumulate in the bladder—the uterus—the cavities of the pleura—peritoneum—pericardium—arachnoid—tunica vaginalis—in the cellular tissue all over the body,—and in the parenchyma of organs. De Boisement, in his excellent Thesis on Pneumatoses,* mentions a case of gaseous matter being formed within the synovial membrane of the knee joint, and from the analogy between synovial and serous membranes, it is curious that no similar case (as far as I can discover) should be on record.†

* Recherches sur les Pneumatoses, par A. Briere de Boisement. A Paris, 1825, p. 24. *Thesis, No.* 201, *quarto.*

† My friend Dr. Duncan has informed me of a case somewhat similar to that mentioned by De Boisement. It occurred in the practice of the late Dr. James C. Gregory, and under the observation of Dr. Duncan. The patient was a woman of thirty-six years of age. Her

In many animals air is an ordinary and natural secretion. Such is the gaseous matter contained in the swimming bladder of the fish; but what is more to our purpose, in many of the cold-blooded animals, air appears to circulate along with the blood. Reichel frequently observed globules of air in the blood of frogs;* and Spallanzani saw the same in that of salamanders.† Blumenbach states that he has seen air vesicles so frequently in the blood of amphibia, and fishes, that he considers them to be constantly present.‡ Similar observations have been made by Redi, Caldesi, and Morgagni.§

Anormal formations of air are by no means uncommon, both in the inferior animals and in the human subject, in certain states of disease, and they sometimes exist without any other morbid phenomena being apparent. Bags containing air have been found in the abdominal cavities of healthy pigs; and occasionally air is contained in cysts in the human subject.‖

In hysteria, air frequently accumulates in very large quantities in the stomach and intestines; and in peritonitis the formation of gaseous matter is a common occurrence.

disease was cholera. In consequence of the injection of the saline solution, phlebitis supervened. During life it was suspected that within the cavity of both knee joints there was accumulated a mixture of air and pus, and upon dissection a few hours after death, such was proved to be the case. In this instance, however, it is probable that the gaseous matter was produced by the decomposition of the pus.

* De Sanguine motu experimenta, p. 16. Leipsic, 1767.

† Experiences sur la Circulation, &c. p. 158.

‡ Kleine Schriften zur Vergleich. Phys. und Anat. und Naturgesch. gehörig, parag. 71.

§ Morgagni de Sedibus et Causis Morb. lib. i. 2, p. v. § 22.

‖ Dict. de Méd. Article, *Kystes.*

Air may accumulate in the urinary bladder, the uterus, and in other situations, without indicating a state of general disease, and consequently is of trifling importance. The distention of the uterus with air, however, has occasionally given rise to awkward errors, from the affection being mistaken for pregnancy. I was lately informed by a medical friend, of a woman residing near Edinburgh, to whom such a misfortune happened. The baby clothes were ready, and she was in the daily expectation of being brought to bed. One morning, however, having stooped to pick up something from the floor, to her no small astonishment and dismay the contents of the uterus passed of in one continued stream of air.*

Sudden impressions made upon the mind occasionally produce an immediate disengagement of a large quantity of air. Frank mentions a case of a lady, who, on hearing a false report of the death of her husband, fainted, was seized with convulsions, and at the same time became enormously tympanitic. Lobstein, in quoting this case, gives another of the same kind. A man, after a hearty meal, received a piece of bad news. Suddenly his digestion became disordered, and air was formed within his body to so great an extent, as actually to suffocate him.† Hypochondriacs are very subject to the formation of large quantities of gaseous matter within the stomach and intestines.

Spontaneous emphysema has often been observed to a greater or less extent as a sequel of certain epidemics. We

* An analogous case is related in the Lancet, vol. ii. p. 355. Bianchi has recorded a similar case in the Journ. de Méd. de Paris, 1756. Vide also Astruc Traité des Maladies des Femmes.

† Lobstein Traité d'Anatomie Pathol. Tome i. p. 156. A Paris, 1829.

are told by Frank that an epidemic fever which prevailed in Germany in 1772, and another which raged in Bobbio, (a small town in Italy,) in 1789, frequently terminated in a general emphysema. The same author mentions the case of a young lady of Vienna, who used to become emphysematous during every paroxysm of a tertian ague.*

Dr. Sickel gives an account of a woman, who, without any external injury, was suddenly seized with emphysema over the whole body. No bad consequences resulted, and on the following day, the affection had completely disappeared.† The narrator assigns as the cause of the phenomenon that a short time before its occurrence, the woman had eaten some mustard seed, eruca, and a sausage.

It has been stated by Baillie, and other observers, that when air is found in the stomach or intestines of a dead animal, it may generally be also detected in the small blood vessels of these parts. Baillie, after detailing a case of "emphysema not proceeding from any local injury," gives it as his opinion, "that the air was formed from the blood itself, by some peculiar arrangement of its parts, and conducted into the cells of the cellular membrane by very small vessels."‡

Andral§ and other eminent pathological authors speak of gaseous matter being formed in the circulatory apparatus. Lobstein also considers this as established; and he considers gaseous secretions, in whatever part of the body they may be found, as *vital products*, resulting from

* Cyclop. of Pract. Med. Article, *Emphysema*. Lond.

† Sicelii Decad. *quart*. 1744, p. 487.

‡ Transactions of a Society for the Improvement of Medical Knowledge, vol. i. p. 202.

§ Andral Précis d'Anat. Pathol. Tome i. p. 523. Paris, 1829.

some peculiar nervous influence, engendered in the minute ramifications of the nerves embracing the capillaries;* and Gaspard employs the term "*gazeification vitale*" in his essay on the subject.† The experiments of Magendie and Girardin clearly shew that the gas secreted by the intestines is not the result of any chemical decomposition, but is truly a vital secretion. After many careful observations, they found that the nature of the aliment did not influence the nature of the gas which was produced, but that this was invariably the same. In the smaller intestines the gases detected were carbonic acid, hydrogen, and nitrogen; and in the lower bowels they found the same gases, with the addition of sulphuretted hydrogen.‡ From all these considerations, then, it seems manifest, that although in many cases, accumulations of gas within the body owe their origin to chemical decomposition, yet nevertheless they are sometimes the products of a vital action.

Whatever be the explanation of the fact, it is quite certain that emphysema frequently takes place without any lesion, and that in such cases upon dissection air is found in the blood vessels.

There are some curious instances, however, on record, in which there seems at least a very strong probability that during life a very large quantity of air was contained in the blood-vessels. A man twenty-five years of age, who had been ill for fifteen days, was admitted into the Hôpital Cochin of Paris, "with symptoms of typhus fever; he also complained of pain in the left thigh; and whilst he was in a state of delirium, said he had been bitten on the knee

* Lobstein, op. cit. Tome i. p. 162.

† Gaspard Dissert. Physiol. sur la Gazeification vitale. Paris, 1812.

‡ Rech. Physiol. sur les gas intestinaux, § 8. Paris, 1814.

by a dog. The limb was most attentively examined, but not the slightest trace of such an accident could be discovered. The thigh and scrotum were much swollen. He died on the following day. On dissection, eight hours after death, the surface of the body was found soiled by blood which had transuded through the integuments, and some blood had also been discharged from the nose. The whole body was emphysematous, but the left inferior extremity was so to a very high degree. It was double its natural size, of a brown colour, and covered with numerous phlyctenæ, some black, of great extent, and collected in clusters, from which escaped a reddish serous fluid, mingled with a quantity of gas; others white, from which nothing but air escaped. When the limb was pressed with the hand, crepitation was distinctly heard, the abdomen was much distended with gas, and in the intestines were observed those alterations which are so common in cases of typhus fever. Bubbles of air filled the vessels of the pia mater and the left vena saphena. The lymphatic ganglions of the mesentery were enlarged, and contained gas, which took fire from the flame of a taper, and produced an explosion; the same phenomena also followed the exit of the air, which was contained in the legs, thighs, and scrotum."* Weber mentions a case of aneurism containing air.†

According to the experiments of Krimer it appears, that if the blood be pressed out of a portion of an artery, and that portion be isolated by two ligatures, it will soon become distended with air.‡ If this statement be correct, it seems

* Lond. Med. Phys. Journ. June 1831, as quoted in Article *Emphysema*, Cyclop. of Pract. Med. Lond.

† Annotationes Anat. et Phys. p. 6.

‡ Versuch einer Physiol. des Bluts, § 177, 185. Leips. 1823.

to favour the opinion, that the internal coat of an artery has the power of secreting air.

That such is the case we are inclined to believe; and to prevent repetition, the arguments upon which this opinion is founded are here summed up. 1st, Air is found circulating in the vessels along with the blood in certain cold-blooded animals. 2d, Air has been found unmixed with the blood in the human species after death, when from the history of the case there is every reason to suppose that it was in the blood-vessels during life.

Air is secreted by serous membranes, to which the inner coat of an artery bears a close resemblance; and this, when viewed in connexion with the experiments of Krimer, is an argument of considerable weight.*

Another argument might be drawn from these cases of sudden death, in which the only thing found which can at all explain this event, is the presence of a large quantity of air in the blood-vessels. Sometimes the gaseous matter is found only in the vessels of the brain, and to this class of cases Morgagni has given the name of *gaseous apoplexy*. At other times we find the heart distended with frothy blood. From what has been stated above, it is fair to entertain the idea, that the sudden evolution of air within the blood-vessels may occasionally give rise to symptoms similar to those produced by its injection into the veins. This hypothesis is strengthened by the fact, that the formation of air in the living body sometimes takes place with extreme rapidity.

Cases of sudden death, in which the heart is described as

* In Burdach, vol. v. p. 209. is the absurd fancy that air is naturally secreted in the heart and origin of the large vessels, because they empty themselves of their blood without being able to remain collapsed.

having been found distended with air, are not so numerous as those in which the air has been found only in the vessels of the brain. One very remarkable instance is given by Morgagni. "A fisherman of Venice, upwards of forty years of age, and the subject of dyspepsia, was seized when in his boat with an affection of the abdomen, apparently from flatulence, to which he had been previously liable, and suddenly expired." "The body was examined on the following day. *Dissection.*—The abdomen was tumid from gas, with which the stomach and intestines were inflated." "The heart was large and flaccid; and both of the ventricles, and the right auricle, contained frothy blood." Most of the veins, the pulmonary artery, the aorta and carotids, also contained a frothy mixture of air and blood. The scrotum was greatly inflated with air.* Pechlin gives a case of a somewhat similar nature,† upon which Nysten remarks—"On reconnoit que la mort doit etre spécialement rapportée à la distension du ventricle pulmonaire par un gaz qui empechoit le sang venieux d'y arriver."‡ Unfortunately the symptoms which immediately preceded death are not detailed. Ruysch gives an account of a woman who died suddenly, and in whom the heart was found distended with air.§ A similar case is described by Grætz, and is quoted by Morgagni (Lib. i. ep. v. § 20.) and Nysten, (p. 7, and p. 174.)

The following are perhaps two of the most important of these cases of which we have any account. The one is given

* Cooke's Morgagni, vol. i. p. 80. Lond. 1822 from Morgagni, v. 17.

† Observ. Physico-Medicae. Obs. lvii. p. 135. Hamburgh, 1691.

‡ Opera Omnia, 1737, p. 9.

§ Mr. Percival, veterinary surgeon in the 1st Life Guards, has published an account of a horse which died suddenly when under treatment

by Nysten upon the authority of his friend Dr. De Jaer. The subject of the observation was a shoemaker of forty-five years of age, who had for the last fifteen years of his life been afflicted with spasmodic asthma, and had generally about seven violent accessions during the year, which came on without any premonitory symptoms. At the commencement of one of the exacerbations, he was brought to the " Hôpital Cochin" of Paris, where he died on the third day. The body was opened twelve hours after death, when it was yet warm. The left ventricle and the arteries contained no blood, but the right auricle and ventricle, and the whole venous system were distended with frothy blood. All the organs were in their natural state, and the muscles were very firm and red.

What gives additional importance to this case is, the short time which was allowed to elapse between death and the examination of the body.

The other case to which allusion has been made occurred to M. Laumonier, in the hospital of Rouen.—A woman, aged fifty-six, died suddenly from an attack of asthma, a disease to which she was subject. The body was examined twenty-four hours after death. The season was winter; and there was not the slightest trace of putrefaction. There was emphysema in various parts of the body, and the internal coat of the carotid artery had a red appearance, as if resulting from inflammation. The heart was very much distended, and its right cavities were filled with gaseous matter of a peculiar smell.

for a catarrhal affection, the heart of which, upon dissection, was found enormously distended with air. (Veterinarian, vol. x. p. 65. Lond. Feb. 1837.) It is exceedingly to be regretted that there is no mention made of the time which elapsed between death and dissection.

In the Medical Observations and Inquiries there is a singular case mentioned, which I am somewhat inclined to classify with the above. The patient during life was sensible of a noise within the thorax resembling "a stream of water passing over obstructions, or passing over a narrow confined place. He was subject to exacerbations, and when he varied his position the circulation became confused, and as it were wholly carried on in a corner of his heart, which at such times beat with a whizzing noise. During his illness he felt the greatest pain when the noise seemed least; so that when speaking of his situation he had a common expression that *Gush was his friend;* while Gush stood by him he should live."—At last he died. Upon dissection the pericardium was found loaded with fat. The heart *in situ* was longer and more pointed than usual for its size. The right auricle was much enlarged, and very thin, bearing strong marks of inflammation. The ventricle having lost its usual firmness and colour, was so transparent, as in a manner to admit an inspection into its very substance. *Upon cutting into these two cavities a considerable quantity of air rushed out, and upon laying them both open they appeared as totally void of blood as if they had been washed clean. The interstices between the chordae tendineae were full of air bubbles.* A variety of less remarkable morbid appearances were noticed. Unfortunately it is not stated at what period after death the inspection was made, so that the case standing, as I believe it at present does, *per se*, is deprived of much of its value.*

Without laying any weight whatever upon this last case,

* Med. Observ. and Enq. vol. vi. Case of M. Houlder, by Mr. R. B. Cheston, surgeon at Gloucester. Communicated by Dr. William Hunter.

it does not seem too hypothetical to suggest that in the cases which occurred in the "Hôpital Cochin" and the Hospital at Rouen, the immediate cause of death was the presence of a large quantity of gaseous matter in the heart. We have seen that violent mental emotions sometimes occasion the disengagement of large quantities of air. Is it possible that the rapid evolution of this elastic fluid is ever the immediate cause of those instantaneous deaths which frequently follow sudden and immoderate emotions of joy or grief?

Death it would appear sometimes takes place from the sudden disengagement of gas within the vessels of the brain, constituting the *gaseous apoplexy* of Morgagni and other authors; but a mere reference to this subject must suffice, as the appropriate limits of a Thesis have I fear been already exceeded. The idea of Morgagni was, that the cause of death was the pressure exerted upon the brain by the air; but Bichat thought that in some cases the quantity of air found is so small as not to give plausibility to this explanation, and contended that the life of the brain was destroyed by some peculiar and subtle action exerted upon it.*

All that can be said with confidence, then, in reference to this subject, is, that there are various facts and arguments which render it exceedingly probable, that owing to the sudden formation of air within the blood-vessels, death may be produced either by arresting the contractions of the right side of the heart, or by producing a fatal action on the brain.

* Sur la Vie et la Mort, Part ii. Article 2de, § 2.