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A

TREATISE

ON

HEMORRHAGE.

A

TREATISE

ON THE

PROCESS EMPLOYED BY NATURE

IN

SUPPRESSING THE HEMORRHAGE

FROM DIVIDED AND PUNCTURED ARTERIES,

AND ON THE

Use of the Ligature;

CONCLUDING

WITH OBSERVATIONS ON SECONDARY HEMORRHAGE.

The whole deduced from an extensive series of experiments, and illustrated by fifteen plates.

BY J. F. D. JONES, M. D.
Member of the Royal College of Surgeons of London.

Le Desir de découvrir le vrai, doit être dirigé dans sa marche par un grand nombre d'expériences.
POUTEAU, *Melanges de Chirurgie.*

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TO

J. R. FARRE, M. D.

THIS TREATISE IS INSCRIBED,

AS A TRIBUTE OF

AFFECTION AND FRIENDSHIP,

BY

THE AUTHOR.

ADVERTISEMENT.

THE subjects of this treatise, whether we consider them in reference to the patient, or the surgeon, are inferior to none in the interest which they ought to excite. The brave, the unfortunate, and the diseased, are those who plead for that aid which is to rescue them from instant danger. The surgeon never suffers greater anxiety, than when he is called upon to suppress a violent hemorrhage; and on no occasion is the reputation of his art so much at stake. There are only two modes by which we are enabled to obtain any knowledge on these subjects: first, by patient observations made on the human body; and secondly, by direct experiments on brutes. War, accidents, and disease, have never been wanting, and yet the re-

cords of our profession afford us but few and detached observations on the suppression of hemorrhage, if we contrast the knowledge we possess with the importance of the subject. Rash conjecture, and idle hypothesis, resting on partial observation, have usurped the place of that truth, which could only be discovered by a series of observations through every stage of a process, which, one would think, claimed the strictest investigation from the moment that surgery became an object of individual pursuit. The author of this treatise has endeavoured to supply that deficiency by a series of experiments on brutes. He has not laboured to prove from the structure, the functions, and the morbid changes, of their arteries, that his experiments afford an unerring guide, as to corresponding changes in the arteries of the human subject; but he has diligently sought after such experiments of eminent physiologists or surgeons as would add weight to his own, and especially after such observations, made on the human subject, as corresponded with the results of his experiments. This is the balance by which he would have his labours tried, and, if found wanting, rejected. Some of the most interesting of these observations he

has interwoven with the body of the work, and others he has thrown into notes at the end of it.

This treatise, though small, is the fruit of much labour and expense: it is the author's earnest wish, and has been his endeavour, to render it useful. The experiments on the several subjects of it require to be extended to ascertain certain events connected with them, which are not yet fully explained: this it was his intention to have done, but before he could accomplish it, he was called away to the West Indies, and he felt himself under the necessity of laying the work before the public in its present form, or of deferring its publication to an uncertain period. He preferred the former from a consideration of the importance of the subjects, of the lively interest they derive from their connexion with the circumstances of the times, and from the belief that he had contributed to advance the knowledge of them. He particularly regrets that he was obliged to hurry over that part of his work which demanded the most laborious investigation, and to limit it merely to the abuse of the ligature. It was his intention to have much extended his inquiries with re-

gard to secondary hemorrhage; but it is in vain to say what he meant to have done! perhaps future opportunity may enable him to supply what he deems to be deficient: at any rate, he solicits the attention of surgeons of hospitals, of the army, and navy, to all the minute circumstances of these subjects, than which none more important can ever claim their consideration.

He has only a few words more to say, addressed to men out of the pale of his profession, into whose hands this little book may fall, whose opinions he esteems, and whose feelings he honours. He regrets the necessity of obtaining even this important knowledge by the sacrifice of brutes. But when we remember the incessant scourge of war which has followed man through all the ages of his history—not to mention the consequences of accident and disease—it is not too much to assert, that thousands might have been, and may still be saved by a perfect knowledge of these subjects; which can only be directly obtained by experiments on brutes; indirectly, and very slowly, by observations on the injured arteries of man; and

even these cannot be made until he has fallen a sacrifice to the want of assistance, or to the imperfect knowledge of the surgeon.

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PREPARATORY CONSIDERATIONS.

THE changes produced on arteries by accidents, and the surgical operations to which they are subjected, have a certain relation to their structure. The subjects, therefore, of this Treatise naturally suggest a few preliminary observations on the structure of arteries; but only such a description will be given, as may suffice for the explanation of the phenomena which they exhibit, when influenced by accident or art.

The substance of which arteries are composed is divisible into distinct parts, which have been called tunics or coats. Three coats, which have received various names, can be readily demonstrated, and may be simply and clearly distinguished by the terms—Internal, Middle, and External.

The internal coat, although extremely thin, is very close in its texture, and gives to an artery a smooth and polished lining; it is elastic, and firm, considering its delicate structure, in the longitudinal direction, *but so weak in the circular as to be very easily torn by the slightest force applied in that direction.* The mor-

bid changes, which have been observed in it, prove that this coat is vascular;* and some experiments have been related to show the probability of its being sensible.†

The middle coat, which is the thickest, is formed by numerous layers of firm, compact, fleshy fibres, of a pale red colour, passing in a circular direction, but appearing rather obliquely connected and interlaced with each other, than forming complete circles. These fibres are of a peculiar nature, are well supplied with nerves, and resemble, in form and disposition, muscular fibres, but differ from them in possessing a remarkable degree of elasticity. Their elasticity keeps an empty and dead artery open and circular; for this coat, when detached from the internal and external coats, still preserves the cylindrical form, whilst they, on the contrary, in a state of separation, become flaccid and collapse. As this coat has no longitudinal fibres, *the circular fibres are held together by a slender connexion, which yields readily to any force applied in the circumference of the artery.* The middle coat is intimately connected with the internal and external by very short and fine cellular membrane.

The external coat, anatomically considered, is so simple, that many authors have thought it sufficient

* "I have more than once observed the cavity of a large artery "almost blocked up by a steatomatous thickening of this coat, and "frequently I have observed purulent matter collected in it." Remarks on the Coats of Arteries, &c. by Alex. Monro. Edin. Med. Essays and Observations, Vol. II.

† Bichat, Anatomie Generale.

to say, that it is formed of condensed cellular membrane, which becoming gradually of a looser texture connects the artery with the surrounding parts; but the importance which is attached, in a surgical view, to this coat, renders a more particular account of it highly necessary and interesting. Although ultimately resolvable into cellular membrane, yet it derives from the particular arrangement of its component fibres a characteristic appearance, which distinguishes it from cellular membrane, and entitles it to be ranked as a proper coat of an artery. Internally, or next to the middle coat, its texture is close and smooth, externally more open and rough, in consequence of the cellular membrane by which it is connected with an additional covering. The whole is remarkable for its whiteness, density, and great elasticity. If an artery be surrounded by a tight ligature, its middle and internal coats will be as completely divided by it as they can be by a knife, whilst the external coat remains entire; a fact, which will be commented upon in another part of this treatise, and shown to be connected with important circumstances. The strength therefore of an artery depends chiefly on its external coat, which answers, in some respects, the purpose of a strong fascia.

The three coats which I have just described are the only proper coats of an artery; but the different arteries, while in their natural situation, are surrounded with fine cellular membrane that connects them with additional coverings, called sheaths, which are formed within the cavities of the body by the investing membrane peculiar to each, and in other parts by

fascia, or cellular membrane. The fine cellular membrane, the bond of connexion between arteries and their sheaths, varies in length in different parts, and gives an artery a flocculent appearance. *If an artery be divided, the divided parts, owing to their elasticity, recede from each other, and the length of the cellular fibres connecting the artery with the sheath, admits of its retracting a certain way within the sheath:* an important fact, the application of which will be made in a future part of this treatise, that describes the natural process by which hemorrhage is stopped.

In performing the experiments, which will be subsequently related, it was not my intention to investigate the long agitated question respecting the action of arteries, whether it should be ascribed to their elasticity alone, or their elasticity and muscularity conjointly. I have had, however, frequent opportunities, in the course of my experiments, of observing appearances, which incline me strongly to the latter opinion, slightly modified. These appearances made so conspicuous a part of the process, to which my attention was more immediately directed, that I was induced to discuss the subject at some length in my Thesis. Here we are only concerned to notice one important fact relating to the action of arteries, namely: *that when an artery is divided, its truncated extremities contract in a greater or less degree, and the contraction is generally if not always permanent.* But I have only once seen a distinct contraction, produced by a mechanical stimulus, *while the artery remained entire.* It happened in an artery on which the effect of galvanism was tried; but it was uncertain, even in this instance,

whether the contraction should be referred to the irritation of the wire of the galvanic pile, or to the galvanic influence, which it conveyed.

Arteries are supplied not only with small arteries and veins (the vasa vasorum), but also with absorbents and nerves, and have, in these respects, a similar organization to the other soft parts of the body. *This structure makes them susceptible of every change to which living parts are subjected in common; enables them to inflame when injured, and to pour out coagulating lymph, by which the injury is repaired, or the tube is permanently closed.*

CHAPTER I.

ON THE PROCESS WHICH NATURE EMPLOYS FOR SUPPRESSING THE HEMORRHAGE FROM DIVIDED ARTERIES.

SECTION I.

HEMORRHAGE, the inevitable attendant on operative surgery, impresses mankind with a sentiment of horror, and may, on this and many other accounts, be considered as one of the most formidable opponents to its improvement. It obscures, retards, and embarrasses the progress of every operation; and the just dread of its fatal consequences is the chief cause of diffidence in the operator. But not only as a consequence of surgery is hemorrhage to be feared; it is also one of the most alarming and dangerous accidents, which surgery is called upon to relieve. "Un sentiment naturel attache à l'idée de perdre son sang, un terreur machinale, dont l'enfant qui commence à parler et l'homme le plus decidé, sont egalement susceptibles. On ne peut point dire que cette peur soit chimérique. Si l'on comptoit ceux qui perdent la vie dans une bataille, on verroit que les trois quarts ont

"peri par quelque hemorrhagie; et dans les grandes "operations de chirurgie, cet accident est presque tou- "jours le plus formidable."*

From the interest which Hemorrhage might reasonably be expected to excite, in consequence of these very obvious and important views of it, we cannot fail to be astonished at the long period, during which practitioners had contented themselves with empirical attempts to check it by drugs, or by the insecure, yet terrible means of caustic and fire; and we naturally inquire, how any circumstance so alarming in its nature, so fatal in its effects, should have remained so long uninvestigated.

But although, at first sight, it may appear strange, that a subject so intimately connected with the interests of humanity should have been thus inadequately attended to; yet when we reflect, that, in former ages, the examination of the dead was opposed by violent prejudices; that a total want of rational and scientific modes of investigation circumscribed the knowledge, and supported the vague and hypothetical doctrines of those days; and finally, that the nature of the inquiry, which the subject demanded, was by no means inviting; we shall perhaps be less surprized, that the works of the ancients, so remarkable for valuable observations on most other subjects, should be destitute of accurate information on this; and that it should have remained for the illustrious Mr. Petit

* Morand, Mem. de l'Acad. Roy. de Chirurgie, Vol. V. 8vo edition.

to make the first attempt, in the year 1731, to give an account of the means which Nature employs for the suppression of hemorrhage.

A subject which had attracted the notice of Mr. Petit, was not likely to remain much longer in obscurity; his example soon procured the attention of others, and from that period we find many of the most eminent surgeons engaged in elucidating it.

Fortunately Mr. Petit's assiduity was not diminished by his first memoir. Not content with having brought the subject into notice, and laid the foundation for its future development; he appears to have lost no opportunity of confirming and extending his former observations; and in the course of a very few years he enriched it with two other memoirs, which, together with the first, will ever be considered, by candid readers, as invaluable contributions to surgery, and indubitable proofs of his penetration, accuracy, and fidelity. To these memoirs I shall often have occasion to refer, in the course of the following treatise.

I shall now proceed to give a view of the various theories, which I have been able to meet with on the subject.

But, previous to stating Petit's theory, it is necessary that he should be exculpated from the censure which a late author* has unjustly and indiscriminately passed on him for experiments and doctrines which

* Mr. J. Bell. Principles of Surgery, p. 170.

were made and maintained by Mr. Petit the physician. It is unnecessary to inquire into the propriety of the ridicule which Mr. Bell has endeavoured to cast on these experiments; I only wish that attention may be paid in future to the distinction of Mr. Petit *le Chirurgien*, and Mr. Petit *le Medecin*, uniformly prefixed to the respective Memoirs of these gentlemen. In speaking of Mr. Petit, in the course of the following pages, I beg it may be understood that I allude to the surgeon, unless the contrary be particularly specified.

Mr. Petit conceived that Hemorrhage, from a divided artery, is stopped by the formation of a coagulum or clot of blood,* which lies partly *within* and partly *without* the vessel. The external portion is formed, he thought, by the last drops of blood which issue from it; the internal portion, by the blood contained just within its divided extremity; the former he called the "Couvercle;" the latter, the "Bouchon." The clot, he said, afterwards adheres to the internal coat of the vessel, to its orifice, and to the surrounding parts. To this he added, that when hemorrhage is stopped by the application of a ligature, a clot is formed above the ligature; and the coagula, under these different circumstances, differ only in figure. This view of the subject led him to recommend compression to support the clot, that it may not be pushed away by the impulse of the blood.

Although the validity of most of these observations is unquestionable, yet it must be allowed, that the theory

* "Caillot de sang."

is very incomplete; and that Mr. Petit erred in his manner of accounting for the appearances which he had observed; his errors, however, did not result from want of judgment, but from the nature of the process, which could not be understood, without successive observations through its various stages; and, as Mr. Petit does not relate any experiments, it is reasonable to infer, that his doctrine could only have been deduced from the irregular and partial observations which he was enabled to make on the human body in the course of his practice.

In the year 1736 Mr. Morand published a Memoir, in which he added many very interesting remarks to those which had been made by Mr. Petit. He admitted, that the formation of a coagulum had some effect in stopping hemorrhage; but contended that the changes which the artery undergoes also contributes to that effect. These changes he described to be a sort of corrugation, or plaiting of the circular fibres of the artery, by which its canal is diminished; and a shortening and consequent thickening of its longitudinal fibres, so as nearly to fill it up: this latter effect he conceived to be produced, when an artery is completely divided, and that it constitutes the principal means by which, in such cases, the hemorrhage is stopped. He added, that the corrugation, or puckering, of an artery, may take place, so as to obliterate its cavity, provided pressure be made round it: as by a ligature.

It is evident that Mr. Morand alluded to the contraction and retraction of arteries, and that he erred chiefly in his explanation of the manner in which they are

produced; thus, besides the imperfect account which he gave of the contraction, which he sometimes called the frowning* of the artery, he imputed the retraction to longitudinal fibres, which, according to the most accurate anatomists, are not to be found in the arteries of the human subject.

It is obvious, from the terms Mr. Morand employed, and the plates he published, to explain the state of the artery, that he had very inaccurate ideas of the structure and action of arteries; yet this does not affect the truth of his general conclusion: that the change produced on a divided artery, contributes with the coagulum to stop the flow of blood; and that, if it be possible to adduce cases in which either the artery or the coagulum alone effected it, they will at least be very rare. He endeavoured further to support his opinion, by observing, that the extremity of the divided artery is the mould for the coagulum, which owes its figure to the impression made on it by the artery; for, said he, if the diameter and form of the vessel remain the same, when cut through, as at the moment of the incision, the coagulum formed in its extremity will be cylindrical, uniform at its ends, and liable every moment to be pushed away by the column of blood, impelled against it.

Mr. Sharp, nearly at the same period, supported the same doctrine, as may be found in the second edition of his Operations of Surgery, published in 1739. It is more concisely and better expressed than Morand's;

* "Froncement."

thus: " The bloodvessels, immediately upon their di-
" vision, bleed freely, and continue bleeding till they
" are either stopped by art, or at length contracting
" and withdrawing themselves into the wound, their
" extremities are shut up by the coagulated blood."—
This doctrine Mr. Sharp gives incidentally; leaving it unsupported by experiment or observation; so that it does not appear whether it is his own, or borrowed from another. It is not comprehensive enough; but, as far as it goes, it accords with the truth.

The next theory which I am to notice is Mr. Pouteau's. It is prefaced with many very judicious observations, peculiarly applicable to the subject; and from which one might have expected that he had completely exhausted it, and had left nothing for future inquirers to discover or confirm. " Le desir si louable de décou-
" vrir le vrai, doit être dirigé dans sa marche par un
" grand nombre d'experiences: . . . . pour se
" persuader qu'on a bien vu, il convient d'avoir re-
" gardé long tems et sous differens points de vûe."*

But unfortunately these judicious remarks appear to have been intended rather as strictures on Messrs. Petit and Morand, than as maxims which had regulated his own inquiries and conclusions: had he indeed been influenced by them, he would have spoken more favourably of the theories of Messrs. Petit and Morand, and would have presented us with a view of the subject very different from that which he produced.

* Melanges de Chirurgie.

But let it not be thought, that I am disposed to deal captiously with Mr. Pouteau, in retorting on him his own judicious and valuable observations: far be it from me to delight in pointing out the errors of those who were conspicuous for their merit at the period in which they lived; and to whom we are indebted for much valuable information: on the contrary, it is from respect to such men, that I undertake to exculpate Petit and Morand from his censure; nor am I less ready to acknowledge the fidelity with which Mr. Pouteau has performed his promise: " Je rapporterai donc " ce que j'ai vû en historien fidele qui ne craint pas de " dire la verité même en contredisant."

As a faithful historian he is indeed entitled to much praise; for in his memoir on the subject are recorded almost all the appearances exhibited in the different stages of the process; those which give the most unquestionable support to the theories which he condemned, as well as those, which he unfortunately selected for the formation of his own: and hence, his account of it is peculiarly interesting; not only as a confirmation of the former, but also for the valuable additions which he made to them. For these reasons it will be necessary to pay considerable attention to his memoir.

Mr. Pouteau denied that a coagulum is always to be found after the division of an artery; and when it is, he thought it should be considered only as a feeble and subsidiary means towards the suppression of hemorrhage. The retraction of the artery, he said, has not been demonstrated; and that, at any rate, it is not more

effectual than the coagulum. He asserted, that the tumefaction of the cellular membrane, at the circumference of the cut-extremity of the artery, forms the principal impediment to the flow of blood; and the application of a ligature to an artery is useful, by promoting a more immediate and extensive induration of the cellular substance.

It appears, at first, almost impossible to reconcile this theory with the two former; but to account for the very striking difference between them, it is only necessary to observe, that although, in the beginning of this Memoir, Mr. Pouteau relates two experiments, which had been performed on horses, which being examined *a short time after*, presented appearances exactly coinciding with the doctrines of Petit and Morand, yet he preferred giving an explanation of the natural means by which hemorrhage is stopped, from observations made on arteries many days, and even *weeks, after they had been divided*, and on which *some artificial means* had been applied to suppress the hemorrhage. Thus he first informs us, in a general way, that after amputations of arms, legs, and thighs, in which the flow of blood had been stopped by the ligature, compression, or caustic, he *very seldom* found any traces of a coagulum; and then gives a more particular account of four examinations in which he had been equally unsuccessful: they were made on the stump of an arm, eight days after amputation; of two legs, one ten days, the other three weeks after the operation: and, finally, of a thigh, four weeks after amputation. In all of these cases some artificial means had been used to suppress the hemorrhage; and yet,

these are the principal instances, and the periods of examination, from which Mr. Pouteau undertook to write a "Memior on the means which *Nature* employs "for the suppression of hemorrhage;" and that too in opposition to the descriptions of those means, which had been previously given, and notwithstanding the ample illustration of them afforded by the first experiments which he performed on horses.

We find Gooch also entering the lists against Petit, and thus claiming the merit of a prior opinion: "Since "I wrote these papers, I have observed Mons. Pou- "teau, senior surgeon of the Hôtel-Dieu, at Lyons, "in his Melanges de Chirurgie, printed in 1760, and "Mr. Kirkland, an eminent surgeon in this kingdom, "in his Treastise upon suppressing hemorrhages from "divided arteries, published in 1763, differ in their "sentiments from Mons. Petit, whose hypothesis is, "that hemorrhages are stopped after amputations by "coagula of blood, formed several inches up the ar- "teries, as appears in the Mem. de l'Acad. Roy. des "Sciences. I have the satisfaction to find the experi- "ments, made by these two gentlemen, fully support "my opinion upon this subject, which I wished to "have had an opportunity of making myself, when I "published it among some cases and remarks in sur- "gery, in the year 1758."—Gooch's Chirurgical Works, Vol. I. p. 172, note, published 1766.

The opinion referred to, and which he set up in opposition to what he considered as defective experiments or crude observations of Petit, he thus expressed in his cases in surgery: "According to that hypothesis

" (meaning Petit's) the coagulated blood must either " remain in the vessels, or liquify and return in a putrid " state; against which, I think, many weighty objec- " tions might be brought, and experiments made, to " put the matter beyond controversy. It appears to " me highly reasonable, that the native heat of the " part, and the action of the vessels, keep the blood " in a state of fluidity fit to be received by the colla- " teral branches, when checked by natural or artificial " means in its direct progressive course, after ampu- " tation of the limb, and that the divided vessels " then retracting, collapse and coalesce as far as their " first ramifications, having their mouths soon sealed " up with flesh, growing from the nutritious vessels, " which work of Nature is pretty evident upon the " stump." Yet these experiments, to put the matter beyond controversy, Mr. Gooch did not make, but flattered himself that his opinion had been sufficiently confirmed, and fully established by the imperfect experiments and observations of Messrs. Pouteau and Kirkland; I call them imperfect, because they were partial: that series was wanting, without which every natural process that is performed by successive stages must be misunderstood in proportion as its investigation has been less complete. Mr. Gooch afterwards, in the first volume of his surgery, gave his opinion on this subject more concisely, intermingling some of Pouteau's notions with his own. " When a small artery," says Mr. Gooch, " in a limb or any external part of " the body, is totally divided, its retraction may bring " it under the surrounding parts, and with the natural " contraction of the diameter of its mouth, assisted " by the compressive power of those parts, increased

" by their growing tumid, the efflux of blood may be " stopped."

Mr. Gooch, Mr. White, and Mr. Aikin, considered the experiments and observations of Mr. Kirkland quite conclusive in confuting the doctrine of a coagulum, and in establishing the contraction of the arteries as the means which Nature employs in the stoppage of hemorrhage from divided arteries. In justice, therefore, to the subject, and to Mr. Kirkland, I shall extract some of the most important of those observations on arteries which he had the opportunity of making.

Mr. Kirkland, considering that, when the impulse of the blood is abated by the swooning of the patient, it is very common for considerable arteries to be closed by their natural contraction; and convinced by experiment, that the close contraction observed in arteries to which agaric has been applied, is owing to the firm adhesion of the agaric to the artery, by which its mouth is shut; was led to determine the effect of a temporary pressure sufficient to stop the flow of blood from an artery. The conclusions and opinions drawn from his experiments are here gathered, and brought into one point of view, *viz.*

That hemorrhage from a very considerable artery is easily and effectually suppressed by only making a perpendicular pressure upon the end of the vessel for a few minutes.

That the pulsation, at first, is very plainly seen at its extremity; but after some time it becomes less perceptible.

That the bleeding is not suppressed by congealed blood; but by the vessel being quite close contracted for near an inch or more from its extremity: that by removing the pressure from time to time, it is easy to discover this contraction taking place by a gradual decrease of the stream of blood.

That the artery collapses and gradually closes itself up to the nearest lateral branches, as the resistance towards the ligature abates from the blood passing through those vessels. It appeared to Mr. Kirkland even selfevident that Nature always took this step to suppress the hemorrhage from divided arteries, upon reflection, that the same circumstance constantly happens when the umbilical vessels are divided at the birth of the fœtus.

That the impulse against the end of the artery immediately becomes less, and soon entirely ceases from the blood, upon meeting with resistance, dilating and passing through the nearest lateral branches; and this he thought evident from the gradual decrease, and, at length, the total disappearance of pulsation.

That the contraction of the artery, and the alteration in the course of the blood is not long in taking place; after which it probably, like the umbilical vessels, shrinks into a perfect cord, and becomes impervious.

That intercepting the passage of the blood for a while is all that is required from art.

Let the following serve as a specimen of his experiments.

"A large horse being tied down, Mr. Peale of Maid-
"stone, then with me, took off one of his hind legs
"about the middle of the thigh. Upon the division
"of the bone the horse drew the stump towards his
"body; at which time the tourniquet slipped off, and
"five arteries, the least of them about the size of a
"wheat straw, some near as large as a goose quill,
"and one much larger, poured out their blood with
"great violence; but an immediate stop was put to
"the flux by a person pressing with both hands upon
"the wound; and, by continuing this pressure fifteen
"minutes, the vessels became so firmly closed as not
"to discharge the least drop of blood. However, I
"passed a needle and thread round one of the largest,
"intending to make an experiment with the ligature.
"The pulsation at first was very plainly seen at their
"extremities; but after some time it became less per-
"ceptible, and the wound was covered with tow,
"which was kept on with very slight bandage. The
"horse was kept alive forty-eight hours after the
"operation; and though he tumbled about, and strug-
"gled much in attempting to raise himself up, yet
"there was not any return of the hemorrhage. After
"he was killed we dissected the thigh, and found
"that the bleeding was not suppressed by congealed
"blood, but by all the vessels being quite close con-
"tracted for near an inch or more from their ex-
"tremity."*

* Kirkland's Essay on the Methods of suppressing Hæmorrhages from divided Arteries.

Mr. Kirkland repeated his experiments, and the results were the same; but he very properly sought to confirm his opinions by observations made on the human subject, and his experience afforded him the following.

Joseph Ayre, of Cadwell, had a spurious aneurism of the humeral artery, on which Mr. Kirkland performed the usual operation in 1757. "The impulse "of the blood against the ligature at the time of the "operation was very great; and as part of the artery, "whose diameter was considerably enlarged, was ex- "posed, its pulsation was remarkably visible; but "upon removing the dressings, three days afterwards, "the pulsation could neither be seen nor felt nearer "to the ligature than an inch and a half:" whence he was led to conclude, "that the artery had collapsed, "and gradually closed itself up to the nearest la- "teral branches, as the resistance towards the liga- "ture abated from the blood passing through those "vessels."*

In proof both of the contraction of an artery, and of the rapidity with which it takes place, Mr. Kirkland proceeds: "I have observed that arteries, as those we "commonly meet with in cutting for the stone, or in "taking off scirrhous breasts, &c. will, for the most "part, if they are wholly divided, be effectually "closed by pressure in three or four minutes. And if, "in taking off a leg, we intercept the course of the

* Kirkland's Essay on the Methods of suppressing Hæmorrhages from divided Arteries.

" blood longer than is usually done, most of the ar-
" teries will be closed, if the patient is in a tolerable
" good habit; as I have learnt, by tying the large
" vessels, without loosening the tourniquet. I took
" off a woman's leg near the middle of her thigh, and
" tied the large artery without loosening the tourni-
" quet: upon setting it at liberty, we observed some
" blood draining down the muscles from one artery
" only; and though it had contracted so much as
" scarce to admit the passage of any blood, yet, by
" the pulsation, it appeared to be a very considerable
" vessel; and, on this account, the ligature was used.
" Several more which did not bleed were discovered
" by a strong pulsation at their extremities; and there-
" fore, instead of dressing the patient immediately,
" we waited ten or fifteen minutes, and gave her wine
" to raise her spirits, so that we might see whether
" they would bleed or not, and thereby prevent our
" being alarmed with a fresh hæmorrhage after she
" was put to bed; but during this time the pulsation
" gradually disappeared, and the bleeding was effec-
" tually stopped. Indeed, since I have attended to
" this circumstance, I have seen it so often happen,
" that I am well convinced, in amputations larger
" vessels have been trusted with lint and flour than
" has been generally imagined; and that when a fresh
" hæmorrhage returns some hours after an operation,
" it is not from small arteries being dilated by an in-
" creased motion in the blood, as has generally been
" thought, but to the principal lateral branches,
" which had closed themselves, being again forced
" open."

Mr. White, whose opinion carries great weight with it, thus gives his unqualified assent to the doctrine of Mr. Kirkland: "*In regard to the means which Nature "employs in the stoppage of hæmorrhages from divided "arteries*, I never thought Petit's theory of a coagu- "lum at all probable: a coagulum of blood formed at "the end of an artery is so far from being of any ser- "vice, except in some few cases where the air cannot "get admission, that it is absolutely prejudicial, as I "have often observed; and should always be removed "before the application of sponge, or any fungous "substance."

"Pouteau's hypothesis, that the swelling of the "surrounding cellular substance closes the artery, "seemed more probable; but I am now convinced, "from several observations, that, according to the "supposition of Mr. Gooch, since confirmed by my "ingenious friend Mr. Kirkland, the arteries, by their "natural contraction, coalesce, as far as their first "ramification."*

Mr. White thinks the following case a good proof of this doctrine;

An old woman had a compound fracture of the fore-arm, which he found it expedient to amputate at the end of three weeks; but she died on the eighth day after the operation. We are only concerned in the state of the truncated arteries, which had been stopped with sponge, and of whose dissection he gives the

* White's Cases in Surgery.

following account: "Laying bare the humeral artery, "I cut it open to the place where it divides into the "radial and ulnar branches. I then introduced a com- "mon silver probe into each branch, which passed "very easily to a certain point, which seemed about "an inch from the extremity of the stump; but could "go no further. I then used bristles, and pushed "them with all the force they would bear; but they "stopped at the same place. I next laid open the "arteries to their extremities, and found them intirely "closed, near an inch from the end of the stump, "but from that point upwards their capacities were "not at all diminished, nor was there any coagulum, "or clot of blood, in the vessels, or any where near "them."*

Mr. White adds another example, taken from an artery, *fourteen years after* the operation for aneurism had been performed on it!!

That an artery contracts after it has been divided, I am ready to admit; and the experiments which I shall presently lay before the public, authorize me to say, that the contraction of an artery is an important means, but certainly not the only, nor even the chief means, by which hemorrhage is stopped.

Let us inquire whether in Mr. Kirkland's experiments all the circumstances were natural, so as to justify Mr. White in considering them conclusive as to the "means which Nature employs in the stoppage of

* White's Cases in Surgery.

"hæmorrhage from divided arteries." Mr. Kirkland wished to determine the effects of temporary pressure on arteries, and therefore *in his experiments he applied a tourniquet on the limb, a ligature on the artery, or his finger to the mouth of the artery.* All these are artificial means, taking off the force of the circulation from the extremity of the artery, and allowing it to undergo those changes proper to the new condition into which it is brought. One circumstance only being omitted, the means can no longer be natural; especially when it is that one most important circumstance of all, the source of our anxiety and alarm, namely, the impetuous flowing of the blood through the wound of the artery. It is the hemorrhage itself which resists the contraction of the artery to a degree that would, in almost every instance, be attended with fatal consequences (the artery being supposed large enough to admit of such consequences) but for a coagulum, whose formation, situation, and use, will soon engage our attention.

Mr. White draws his conclusions *from the condition of a tied artery*, in which I am ready to admit that the formation of a coagulum of blood is contingent; and, except under particular circumstances, of no use; and employs them to explain *the condition of a divided artery left to Nature*, in which I shall maintain that a coagulum is, in general, essential to the preservation of the animal.

In order then that we may come at the natural means by which hemorrhage is stopped, the divided artery must be left to itself, the size of the external wound being so regulated that the blood does not flow

faster than comports with the powers of the animal; for it is obvious, that if in a large animal a great artery be divided with a free external wound, the animal must die within the time required for the natural means to restrain the hemorrhage.

I refer the reader to the third section of this chapter, where, in its proper place, it will be shown that Mr. Kirkland himself, under circumstances more nearly corresponding with the natural means of suppressing hemorrhage, is obliged to admit the doctrine of a coagulum of blood.

The last theory which I have to notice, is that lately published by Mr. J. Bell,* who, after freely criticising those which I have already mentioned, confidently asserts, that, "when hemorrhage stops of its "own accord, it is neither from the retraction of an "artery, nor the constriction of its fibres, nor the for- "mation of clots, but by the cellular substance which "surrounds the artery being injected with blood." It is to be regretted, that among the plates which Mr. Bell has very judiciously introduced to illustrate the doctrines of Petit and Pouteau, he has not added one to exemplify his own, which, although it appears to be delivered in very decisive terms, yet, in its affirmative part, at least, is vague and inconclusive. It was perhaps on this account that the author subjoined a copious illustration of it, which I shall also quote, that I may not incur the reproach of having given only a partial and unjust view of his theory.

* Principles of Surgery.

" The stream of blood gradually lessens, because " the artery is emptied, and the resistance to the arte- " rial action taken away; the stimulus being gradually " lessened, the artery every moment acts less power- " fully; and the blood being no longer solicited or " urged on by the arterial contractions, forsakes the " open artery, and moves along the neighbouring " branches. The surgeon claps the point of his finger " upon the mouth of the artery, and holds it there; " the outward bleeding is prevented; the blood is " extravasated into the cellular substance round the " mouth of the artery; the cellular substance is slightly " injected with blood; that blood coagulates, and that " slight barrier is sufficient to restrain the bleeding of " a small artery, till the parts inflame, and the artery " is entirely stopped.

" Supposing the artery still larger and more powerful, " and that it drives its blood very furiously among the " cellular substance, it is not this slight injection of " the cellular substance that will restrain the bleeding. " Whenever the finger is removed the blood bursts " through this slight impediment. The injected cel- " lular substance will not support the artery, unless " the cellular substance itself be also supported. . . .

" . . . . . Retraction of the artery has no " effect in suppressing hemorrhagy, but as it fills the " cellular substance; and this injection of the cellular " substance is but a slight obstacle, fit to support only " the very smallest arteries. The natural powers " which restrain hemorrhagy, do but suppress it for a

" time, and expose the patient to secondary hemor-
" rhage!"

According to Mr. Bell's first position it appears, that the injection of blood into the cellular membrane which surrounds the artery, is the only natural cause, by which hemorrhage is stopped; but as he has just before said that it is not stopped by the formation of clots, we are at a loss to know, how this injection of the cellular membrane effects the suppression of hemorrhage. If we have recourse to his explanation, our curiosity is not gratified, and our embarrassment certainly not diminished, for we there find that the cellular membrane is only " slightly injected with " blood," so that we are not at liberty to infer that it is so completely injected as to compress the artery, and in that way stop the flow of blood. Indeed, however plausible such an assertion might have made the doctrine, it would not have been valid: but, continues the author, " that blood coagulates, " and that slight barrier is sufficient to restrain the " bleeding of a small artery, &c." But what is the nature of this barrier, and in what manner does it stop the hemorrhage? for it is to be remembered that we are previously informed in positive terms, that it is not stopped by the formation of clots; and although, in conformity with this, it is not said that the blood is effused into the cellular membrane, *at the mouth* of the artery, but round it, yet, from what has been said above, it must, I think, be pretty evident that an effectual compression of the artery is not implied.

Left then, as we have been, by the author, to make the best we can of the theory and explanation, the only conclusion at which we can arrive without assistance from him, is, that hemorrhage is not stopped " by the formation of clots, but by the cellular sub- " stance, which surrounds the artery, being injected " with blood, which, according to the illustration, " coagulates;" but as the artery is every where surrounded with cellular substance, the coagulated blood, which stops the hemorrhage, must necessarily be in the cellular substance: we have, therefore, only to discuss the difference between a clot of blood, and coagulated blood, to discover the principal difference between this offspring of Mr. Bell, and what he has been pleased to call Petit's " sickly child."

" Retraction of the artery," says Mr. Bell, " has " no effect in suppressing hemorrhagy, but as it fills " the cellular substance." But let it be observed, that besides filling the cellular substance round the artery, it also fills the cellular substance at the mouth of the artery in a particular manner; for the divided artery by its retraction within its cellular sheath, leaves a space of a determinate form, which, all the circumstances necessary for the suppression of hemorrhage operating, is gradually filled up by a distinct clot. If Mr. Bell really means to confine his doctrine of the natural means of suppressing hemorrhage to the injection of the cellular membrane round the artery with blood, he dwells improperly on one of the attendant circumstances to the exclusion of the retraction and contraction of an artery, and the formation of a dis-

tinct clot—all of them primary means in the natural suppression of hemorrhage, of which abundant proofs will be given in the proper place.

I have chosen to set Mr. Bell's theory in its strongest and best point of view, by confining it to the injection of the cellular membrane with blood; for, in justice to his physiological knowledge, I think it unnecessary to examine the accuracy of the reasoning, by which he would show, that the blood *forsakes* the *open* artery; rather supposing, that, on this occasion, he has hastily adopted the account given by the Editor of the Memoires de l'Academie Royale des Sciences for the year 1735; who, in giving an abstract of Petit's paper, for the year 1731, says: "Dans le cas d'un tronc d'artere "coupé, *le sang qui continue de s'y rendre, ne doit plus* "*y couler que jusqu'à l'endroit, où il rencontrera une* "*branche collaterale entiere dont il enfilera la route*, au "moyen de quoi la circulation s'achevera." And I am still less disposed to dwell on the inconsistency of introducing the surgeon's finger as an auxiliary to the *natural* means by which hemorrhage is stopped.

SECTION II.

Having now given a full, and I trust, accurate detail of the various theories, which have been offered in explanation of the natural means of suppressing hemorrhage; I remark, that although they are all more or less deficient, yet each contains correct and valuable observation; which, however, having been made at different stages of the process, has afforded but partial views of it to each observer, and has thereby given rise to the discordant opinions we have reviewed. It is obvious that a connected series of observations can alone afford a full and satisfactory view of the subject: such a series, whilst it confirms and reconciles most of the facts on which the preceding theories were formed, will prove them to have been deduced from too limited an investigation; and induce us to suspect, that, in some instances at least, their authors have been influenced by a spirit of opposition and innovation, and an unjustifiable propensity to assign the whole effect to one circumstance alone, regardless alike of the observations of others, and of the general analogy of the operations of the animal economy.

The truth of this remark will, I think, appear from the experiments, which in conformity with my plan I proceed to relate.

EXPERIMENT I.

Having laid bare the carotid artery of a horse, I passed a bistoury under it, and completely divided it, leaving the external wound open. A rapid and profuse hemorrhage followed; the animal, after a short time, fell, and very soon expired. The hemorrhage did not cease before its death. The cellular membrane surrounding the divided portions of artery was very much filled with blood; both extremities of the artery were considerably contracted, particularly the one next the head; each was separated from the other, having retracted within its sheath, and thus, in the upper portion, a canal extending about half an inch beyond the extremity of the artery, was formed, but there was no coagulum contained in it, the blood having run off so freely and rapidly as to prevent its formation. See Plate I. Fig. 1.

EXPERIMENT II.

The carotid artery of a horse was laid bare, a ligature passed under it, and the integuments were brought together by sutures; then, by means of the ligature, the artery was drawn out between two of the sutures, and completely divided. The animal bled to death, but not so soon as in the preceding experiment, in which the wound had been left open. The truncated extremities of the artery had retracted about an inch and a quarter, and were very much contracted, but their mouths were open; the arterial sheath and sur-

rounding cellular membrane were very much distended with blood, but the canal of the sheath, left by the retraction of the artery, was not filled up with a clot.

EXPERIMENT III.

The carotid artery of a horse was laid bare between the heart and an obstructed part of the artery; as, in consequence of a previous experiment, I had reason to suppose. The integuments were brought together, and the artery was divided, as in the second experiment. A rapid hemorrhage took place; and the jets of blood corresponding to the action of the heart were very conspicuous. The artery was divided nearer to the heart than in the former experiments, and the animal fell sooner than either of the others; but continued alive longer after falling than they did. A little while before the animal's death the hemorrhage had nearly ceased; scarcely any blood could be observed to flow externally; but in a very few seconds after this period he died.

The cut extremities of the artery were separated nearly an inch: both appeared to be very much contracted, especially that extremity of the artery next the head; but from which no hemorrhage happened, as its canal above had in reality been obliterated by the experiment alluded to: the mouth of this portion of artery, however, was still pervious, and its sheath was injected with blood from the artery below. The sheath of the portion of artery next to the heart, and the surrounding cellular membrane were very much filled

with blood, and a clot had been accumulating in the space left by the retraction of the artery: this coagulated blood, which, in future, I shall call the *external coagulum*, was of a conical figure, its apex being situated near the extremity of the artery next the head, and its base continuous at its sides, with the blood situated between the extremity of the artery next the heart and its sheath, whilst the middle of its base was opposed to the mouth of the artery, but did not shut it up very completely. See plate I. fig. 2.

EXPERIMENT IV.

The femoral artery of a dog was cut across, so as not to leave more than two lines breadth undivided.* The animal died of a rapid and profuse hemorrhage in about five minutes. The surrounding parts were filled with blood, but the external coagulum was not formed.

EXPERIMENT V.

Immediately after a horse had been knocked down, his carotid artery was laid bare by a small incision, and separated from a part of its sheath, so as to admit a finger under the artery; when, with a jerk of the finger, it was torn through. The portion of artery next the head instantly retracted within the wound, the other portion hung out from the wound an inch and a half; and from this the hemorrhage was profuse,

* See Note A.

but from that it was comparatively feeble. After the hemorrhage had continued ten or fifteen minutes, the horse raised his head, and began to move his legs; and, in the course of ten minutes more, kicked with such violence, that it was necessary to pass a knife into his chest. Previous to the division of the great vessels, the jet of blood from the portion of carotid hanging out at the wound, had diminished both in size and strength.

Dissection. The retraction of the portion of artery next the head was considerable. It lay in a bed of coagulum, formed by a complete injection of its sheath with blood. The artery being torn from this bed, drew with it an inch or more of the innermost lamina of its sheath, or that portion of it in which a canal had been formed by the retraction of the artery. The portion of sheath projected beyond the ragged extremity of the artery, its cells were distended with blood, and supported the external coagulum against the lacerated end of the artery, which it almost shut up. The sheath with its coagulum was of a conical form. The artery was contracted, but by no means to such a degree as was necessary to stop the hemorrhage independently of the other natural powers, which are combined for this important end. About half an inch of sheath was pendulous from the portion of the artery, which hung out at the wound. This sheath, its canal being cut open, appeared much thickened internally with a coagulum entangled in its cells. This appearance partly explained the gradual diminution of the jet of blood.

EXPERIMENT VI.

A very small incision was made in the neck of a horse, so as to expose only half an inch of the carotid artery. A ligature was made on the artery to prevent hemorrhage from the portion next the heart; and just above this ligature the artery was divided upon a director. The external wound being left open, the hemorrhage was profuse. A tea-cupful of blood, taken immediately after the division of the artery, coagulated in five minutes and a few seconds; the same quantity, taken a quarter of an hour after (by which time the animal had lost an immense quantity of blood, and appeared very feeble), coagulated in three minutes and a half. The stream of blood had now diminished, but the horse began to show signs of great restlessness, and in the course of five minutes more fell. After this very little blood flowed. In this state, to prevent mischief, he was despatched by the slaughterer, when in articulo mortis.

Dissection. The effusion of blood in the surrounding parts, even in the sheath, was very inconsiderable, because the artery was exposed by a direct wound, that had disturbed the parts but little, and was open; and also that portion of the artery which received the blood in the direct course of circulation, and would have driven it furiously into the cellular substance, was tied; and although, from the portion of artery next the head, it flowed very freely, yet, owing to the

retrograde course of the blood, and the easy outlet, the extravasation was trifling. The retraction of the artery had taken place to the usual distance, and the cells of the internal surface of the sheath, left by that retraction, were stuffed with coagulated blood, and approximated; and thus the external coagulum was secured, and filled up the space opposed to the mouth of the artery, to which it was closely applied. The mouth of the artery was evidently contracted, resembling very much the upper portion of artery represented in plate I. fig. 2.

The external coagulum was gradually forming in the above experiment; but the blood requiring, at the least, three minutes and a half to coagulate, and the pressure of the integuments opposite to the wound of the artery being entirely taken off, the external hemorrhage was not restrained, so as to admit of the extensive injection of the sheath to support and detain the blood at the mouth of the artery long enough to form the external coagulum; and, in time, to prevent the animal from being exhausted: it did form at last, but too late; and which must generally be the case in very large arteries under the same circumstances.

EXPERIMENT VII.

The femoral artery of a dog was divided, and the integuments were brought together, as in Experiment II., the section of the artery being made as high as it was detached. Half an hour after the hemorrhage had completely ceased, the dog was drowned.

Dissection. A considerable clot of blood was found between the integuments and the artery, covering both of its cut extremities, and adhering to the lower, and to the parts about it: the extremities of the artery were nearly an inch distant from each other: a black cylindrical coagulum was found stopping up the mouth of the upper extremity, and extending at least one third of an inch down from it, and between the vein and nerve. The mouth of this extremity was slightly contracted. The division of the artery appeared to have been made immediately at its connexion with the cellular membrane; this appearance was, no doubt, rendered more complete by the retraction which had taken place. There was an effusion of blood between the artery and its sheath, to the extent of at least two inches: there was also a considerable effusion in the surrounding cellular membrane; but the artery had not the slightest appearance of being compressed by it. On cutting open this part of the vessel, a long and very slender coagulum of blood was found within it, which by no means filled up its canal at any part, nor adhered to the internal coat of the artery. Hereafter I shall call this the internal coagulum, to distinguish it from the external.

About four lines breadth of the inferior portion of the divided artery was detached from the surrounding cellular membrane, its mouth was much more contracted than the upper, and was slightly turned on one side; it adhered to the clot, which filled the wound, and lay over it; and the internal coagulum was very slender and thready.

EXPERIMENT VIII.

The carotid artery of a horse was exposed, tied, and divided between the ligature and the head, as in Experiment VI.; but, as the hemorrhage from so large an artery had hitherto proved fatal, even from that portion of it next the head, when the wound was left open, the integuments were closely confined by sutures. A large tumor immediately formed; but not more than half a pint of blood escaped between the sutures, and this external hemorrhage ceased in a few minutes. The horse was killed at the end of three hours.

Dissection. The retraction of the artery, and the extensive effusion of blood into the sheath, corresponded with the former experiments. The extravasation between the muscles was not to any great extent. To the mouth of the artery the external coagulum was closely applied, in its form not very definite, in its extent equal to the retraction of the artery within its sheath, by which it was supported; and, at the part where the sheath had been wounded, it was continuous with a very large coagulum that filled up the cavity of the wound. The artery being cut open quite to the external coagulum, a long and slender internal coagulum was found, which extended beyond many collateral branches, but did not occupy a sixth of the artery. In all probability this was formed after the death of the animal; for the examination was not made till an hour and an half after the great vessels had been

divided close to the heart, which, of course, would let out the blood from the adjoining part of the carotid; but it would not completely escape from that portion of it next the head. There was no appearance of lymph at the truncated extremity of the artery, to which the external coagulum was applied, nor was the adhesion between them very strong.

EXPERIMENT IX.

The femoral artery of a dog was divided in the manner described in Experiment II. and six hours afterwards the animal was killed.

Dissection. The integuments slightly cohered to a large clot of blood that lay in the wound. The clot being divided, a small quantity of uncoagulated blood was found within it. The sheath of the artery, and surrounding cellular membrane, and, in several places the cellular substance between the muscles, were filled, to the distance of two inches above the divided part, and fully as much below it, with coagulated blood. The superior extremity of the artery was contracted, and its mouth shut up by the external coagulum, which projected beyond it a quarter of an inch, and was turned forward into the clot lying in the wound. A small band of coagulated lymph lay across the artery a little above this extremity. On cutting open the artery, the internal coagulum was seen a quarter of an inch long, and of a black colour, lying in contact with the external coagulum; but neither filling up the canal of the artery, nor any where adhering to its

internal surface. The exact termination of the end of the artery, viewed internally, was rather indistinct. From the extremity of the inferior portion of artery the external coagulum projected a little, and appeared dark. On cutting open the artery, this coagulum, for the space of three lines breadth within its canal, appeared whiter, and firmly adhered all round to its internal surface. This appearance of the coagulum renders it highly probable that the indistinctness of the internal termination of the superior portion of artery was occasioned by an effusion of lymph. The internal coagulum was long and slender; neither filled the cavity of the artery nor adhered to it, but was attached to the whiter part of the external coagulum that lay in the mouth of the artery.

EXPERIMENT X.

This experiment was an exact repetition of the Ninth.

Dissection. The integuments inclosed a considerable clot of blood, which lay over the extremities of the artery. This clot being raised from the extremity of the superior portion of the artery, we found that it covered the external coagulum, which completely shut up the mouth of the artery, and was, for the space of one-third of an inch, *i. e.* as far as this portion of the artery had retracted, of a slightly conical form, and then swelled into a larger portion, which was continuous with the clot, above described, that lay over it. I cut away the superincumbent clot from the external coagulum just

beyond the sheath, where the latter coagulum was beginning to lose its distinctive character. The effusion of blood was as extensive as in the last experiment. The sheath could be distinctly traced over the external coagulum, and was gradually lost on it. The artery was cut open; its termination was not distinct, probably from the cause suggested in the preceding experiment; the internal coagulum was very small and slender, and lay loosely within it.

The appearances of the external coagulum in the inferior portion of the artery corresponded with the above description, except that it was shorter. See plate I. fig. 3.

EXPERIMENT XI.

The carotid artery of a horse was exposed, and a ligature made on it. The artery was detained at the surface over a strong probe, whilst the integuments were brought together by the uninterrupted suture except at this part, but a single ligature was left in reserve to secure them. The artery being divided next the head, it instantly retracted, and the spare ligature in the integuments was drawn. The blood flowed freely between the interstices, but was evidently much restrained by the confined integuments. The animal (which was in poor condition) in the course of fifteen minutes, became very faint, as appeared from its trembling, heaving, and the convulsive twitches about its neck. These fits returned often, and during their continuance the hemorrhage always diminished, but

did not cease externally for an hour. The animal was killed after six hours.

Dissection. The blood was effused to a great distance into the cellular membrane of the contiguous muscles; and beyond this, quite to the angle of the jaw, the neck was loaded with serum. The artery lay in an immense coagulum; its sheath was separated, and its distinctive character confounded by the quantity of blood that had been forced between it and the artery. The external coagulum in the canal of the sheath appeared to be intermixed with lymph, of which a lamina, immediately applied to the mouth of the artery, and closely adhering to it, seemed most distinct. The internal coagulum, of a black colour, was attached nearly to the center of this lymph; it tapered from this, its base, to the first collateral branch, and was so small that it did not occupy a fourth of the canal of the artery, neither did it adhere at all to the internal coat of the artery. See plate II. fig. 1.

EXPERIMENT XII.

The carotid artery of a horse, having been exposed by a small incision, was raised from its bed over a director, and an uninterrupted ligature passed through the integuments, to close them if necessary. The artery was then torn through by a sudden and violent pull with the director. The portion of artery next the head retracted, whilst the other hung out at the wound three inches. The hemorrhage was considerable from the former, and

would have been profuse from the latter, but it was instantly prevented by making a ligature on the artery; the pendulous portion was then cut off, and the ligature in the integuments drawn close. The blood still flowing from the portion next the head, escaped at certain interstices; these were secured, and it soon stopped. The animal was killed eighteen hours after the operation.

Dissection. The artery had been so torn, that the portion of it next the head lay within its sheath four inches above the wound; but if we remember that three inches of the portion of it next the heart hung from the wound, it will appear, that the retraction was not more than ordinary, and scarcely so much. The sheath of the artery was, for many inches, round and firm, from the quantity of blood injected into it. The external coagulum was formed as usual in the canal of the sheath, but its conical shape was more strongly defined than usual. It was very much intermixed with lymph. To it adhered a long black coagulum, filling four inches of the canal of the artery. This was the internal coagulum, and purely of blood, yet it adhered to the artery in very many parts. To account for this unusual appearance, the artery was examined. Its internal coat had been lacerated in numberless parts, and at every laceration there had been an effusion of lymph, to which the internal coagulum adhered. In this instance, contrary to all the preceding and subsequent experiments, the internal coagulum seems to have had some share in the security against hemorrhage, but only in consequence of the injury done to the internal coat of the artery.

EXPERIMENT XIII.

The femoral artery of a dog was completely divided, and the integuments were brought together as in Experiment II. The dog was killed twenty-four hours after.

Dissection. The integuments cohered, by an intervening layer of lymph, to a large clot of blood that lay in the wound, but their edges had not united. The cellular membrane was filled with coagulated blood from the knee to the internal part of the pelvis. The superior portion of the artery was slightly contracted at its extremity, and shut up by the external coagulum of blood, which extended about a quarter of an inch from it, and, becoming rather smaller at its end, was turned forward. On cutting open this portion of artery, its extremity was found filled up, for at least one line's breadth, with lymph, which adhered firmly all round to its internal surface. There was no division between it and the external coagulum, but an obvious difference in colour.

The external coagulum in this, and the Ninth Experiment, was, for some time, supposed to be the extremity of the artery. It resembled the artery both in size and figure; and their attachment being intimate, their junction smoothed over by the sheath, and the parts obscured with coagulated blood, it was not possible to say where the artery terminated, until the parts were dissected, and the artery cut open.

The internal surface of the artery appeared inflamed a little above the external coagulum, and its coats were thickened.

The extremity of the inferior portion of the artery was very much contracted, and just beyond it the external coagulum projected, for it was small, and of a brown colour, and adhered to about two lines breadth of the internal coat of the artery. The internal coagulum had not formed, for the division of the artery had been made immediately above a very large branch.

EXPERIMENT XIV.

The femoral artery of an ass was divided, and the wound of the integuments so secured by the interrupted suture as effectually to stop the external flow of blood, but a large tumor formed under the integuments. On the following day the whole limb was much swollen, particularly near the wound, where the parts were painful to the touch, and hot. The animal was killed twenty-four hours after the operation.

Dissection. The extravasation of blood had been immense, and extended from the pelvis to the knee, yet it did not follow the artery through the triceps, its course being nearer the integuments. The sheath of the artery was loaded with the same from the triceps, where it is perforated by the artery, and upwards. The canal of the sheath supported the external coagulum of blood, which adhered to the mouth of the artery along its internal border. The internal coagulum tapered into the canal of the artery from the external coagulum as its base, and adhered only to it.

EXPERIMENT XV.

The humeral artery of a dog was divided, and the wound in the integuments left entirely open. A very profuse hemorrhage ensued, but the animal soon became faint, and the blood ceased to flow. The animal was killed twenty-four hours after the operation.

Dissection. The surface of the wound was covered with a layer of lymph. There was scarcely any effused blood in the cellular membrane, except in the sheath of the artery, to the extent of two inches, but the artery was not in the slightest degree compressed by it. The truncated extremities of the artery were very much contracted, but particularly the inferior; and each was closed by the base of the external coagulum of blood. These coagula were conical in their form, and connected by an irregular ridge of lymph, which extended in a direct line from the apex of one to that of the other. On cutting open each portion of the artery, the coats appeared very much thickened, and the internal surface inflamed near the extremity, which was filled up, for at least a line's breadth, with lymph.

EXPERIMENT XVI.

The brachial artery of a dog was divided as high up in the axilla as possible, and the integuments brought together. The animal was killed forty-eight hours after the operation.

Dissection. The dog having pulled away the sutures, the wound was found open, and some small portions of coagulated blood in its cavity. The surface of its cavity was formed by a layer of coagulated lymph, which appeared to be very vascular. The surrounding cellular membrane was filled with coagu lated blood, but much less distended than in the expe riments performed on the femoral artery, and from the colour of the parts it was obvious that absorption of the effused blood had been going on. The artery was covered and surrounded by a considerable quantity of coagulated lymph. The superior portion of the artery was conical; a very small part of the external coagulum remained at its extremity, and was of a pale red colour; but close to its termination an irregular ridge of lymph extended in a direct line from it, between two of the brachial nerves, and connected it with the inferior portion of the artery: this lymph appeared to have been effused in the posterior part of the canal of the sheath. The coats of the artery were thickened, and softer than natural; and just above its extremity the internal coat appeared slightly inflamed, and adhered firmly to a brown coagulum, which completely closed the mouth of the artery, occupying about the eighth of an inch of its canal.

The extremity of the inferior portion of the artery was at least an inch distant from the superior, and terminated also in a cone. Its mouth was closed with a coagulum of lymph, which adhered firmly to the internal coat, and extended up the canal a little beyond the part to which it adhered. The coats of the artery,

and especially the surrounding cellular membrane, were thickened by the effusion of lymph.

EXPERIMENT XVII.

The carotid artery of a horse was divided just above a ligature, which had been made on it to prevent hemorrhage from that portion of it next the heart, and the integuments were secured by sutures previously passed. The blood flowed too fast at two or three interstices, but these were closed by additional sutures, and the external hemorrhage presently ceased. A very large tumor instantly formed, but its size considerably diminished in the course of twenty-four hours. The animal was killed sixty-six hours after the operation.

Dissection. The clot, which originally filled the cavity of the wound, and distended the integuments, had nearly disappeared, having been either washed away by the discharge or absorbed. The ends of the artery were separated between one and two inches. The sheath was turgid with blood to the extent of many inches. To the circumference of the cut artery and just within it, the external coagulum, consisting partly of lymph, partly of blood, adhered. Its figure was conical, and it was supported at the mouth of the artery by its intimate connexion with the inner lamina of the sheath, which, by the retraction of the artery, formed a canal for it; and it derived farther support, on all sides, from the blood effused and coagulated between the inner and outermost laminæ of the sheath. The internal coagulum was an inch and a half long, corresponding to the distance between the external coa-

gulum and the first collateral branch. It completely filled the canal of the artery, and had every appearance of having been formed soon after the operation. It was quite detached, and lay two inches above the external coagulum, having, in all probability, slipped from its original situation in handling the parts previous to the artery being opened. See plate II. fig. 2.

EXPERIMENT XVIII.

The left carotid artery of a dog was laid bare to the extent of two inches, and the Galvanic influence applied to it from a moderately strong pile, but which produced no obvious effect: the artery underwent no other than the usual change from exposure to air. Two ligatures were then applied on the artery so as to inclose nearly an inch of it, which had been perforated by the wires of the pile: this portion was cut away. The portion of the artery next the heart was treated in a particular manner; the detail of which, as it wholly relates to the effects of the ligature, I shall introduce in the chapter on that subject: all that now concerns us is the experiment on the other portion of artery. The wound in the integuments was sewed up, and the extremity of the portion of the artery next the head being drawn out between the sutures by the ligature that secured it, the part incircled by the ligature was cut away; the blood immediately flowed in a full stream, but a tumor soon formed, and the hemorrhage stopped. The dog was killed seventy-two hours after the operation.

Dissection. The arteries were injected from the aorta. The dog, which had been a stout and turbulent animal, had torn the sutures out of the integuments, and the wound was quite open. On dilating it, we found that, from the curvature of the aorta to at least an inch above the extremity of the artery next the head, there was a considerable layer of coagulated lymph, in which the artery was completely inclosed, but *not compressed* by it, although it was impossible to conceive a more complete "engorgement"* of the cellular membrane surrounding it. The effused lymph extended over the trachea and the parts on the other side of the artery: it had three deep abscess-like cavities in it; in which a few small clots of blood yet remained.

The extremity of the portion of the artery next the head was so completely surrounded by coagulated lymph, that it was impossible, from an external view of it, to say exactly where it terminated. On cutting it open, we found that the injection had been forced down to its mouth, and was pressing on the internal coagulum of blood, which was very small, and lay loose between it and the external coagulum. The latter shut up the mouth of the artery, was nearly a quarter of an inch long, and terminated in a point under a lamina of lymph, which was continued from the surface of the wound over this coagulum and the ex-

* I make this observation because the state of this artery forms an insuperable objection to Pouteau's doctrine, that the suppression of hemorrhage depends on the "engorgement" of the cellular membrane.

tremity of the artery. The coats of the artery were much thickened. See plate III. fig. 1.

EXPERIMENT XIX.

The femoral artery of a dog was divided, and the integuments were brought together in the manner already described. The animal was killed nine days after the operation.

Dissection. The wound was open, but its extent much diminished. Its surface was formed of a thick layer of very vascular lymph, which, being divided, discovered the truncated extremities of the artery half an inch apart. The cellular membrane surrounding each extremity of the artery, for the space of an inch, was very much thickened with coagulated lymph. The superior portion of the artery was slightly contracted at its extremity, which was completely closed, and filled up with lymph. From this closed extremity extended, about two lines' breadth, a small rounded whitish substance, of the consistence of jelly, which, probably, was the remains of the external coagulum not yet absorbed. Within this portion of artery we found a small conical coagulum of blood, attached at its base to the lymph that closed the mouth of the artery, but not adhering to, nor even appearing to touch, any other point of its internal surface.

The inferior extremity of the artery was much more contracted than the superior, its termination being

very distinctly of the figure of a cone. On cutting it open we found its mouth completely contracted, and adhering to the lymph that closed it. An internal coagulum, similar to that of the superior portion of the artery, was attached to this lymph. The coats of both portions of the artery were very much thickened. See plate I. fig. 4.

SECTION III.

The results of the experiments related in the last section will not allow us to give so concise and simple an account of the process, as has hitherto been done; but they afford us one more satisfactory, because it accords better with the operations of the animal economy, in which we are accustomed to observe the most important changes gradually produced by the co-operation of several means, rather than by the sole influence of any one in particular.

They accordingly show, that the blood, the action and even the structure of arteries, their sheath, and the cellular substance connecting them with it—in short, that all the parts concerned in or affected by hemorrhage, contribute to arrest its fatal progress, by operating, in the case of a divided artery of moderate size, in the following manner.

An impetuous flow of blood, a sudden and forcible retraction of the artery within its sheath, and a slight contraction of its extremity, are the immediate and almost simultaneous effects of its division. The natural impulse, however, with which the blood is driven on, in some measure counteracts the retraction, and resists the contraction of the artery. The blood is effused into the cellular substance between the artery and its sheath, and passing through that canal of the sheath

which had been formed by the retraction of the artery, flows freely externally, or is extravasated into the surrounding cellular membrane, in proportion to the open or confined state of the external wound. The retracting artery leaves the internal surface of the sheath uneven by lacerating or stretching the cellular fibres that connected them. These fibres entangle the blood as it flows, and thus the foundation is laid for the formation of a coagulum at the mouth of the artery, and which appears to be completed by the blood, as it passes through this canal of the sheath, gradually adhering and coagulating around its internal surface, till it completely fills it up from the circumference to the center.

A certain degree of obstruction to the hemorrhage, which results from the effusion of blood into the surrounding cellular membrane, and between the artery and its sheath, but particularly the diminished force and velocity of the circulation, occasioned by the hemorrhage, and the speedy coagulation of the blood, which is a well known consequence of such diminished action of the vascular system, most essentially contribute to the accomplishment of this important and desirable effect.

A coagulum then, formed at the mouth of the artery, and within its sheath, and which I have distinguished in the experiments by the name of the external coagulum, presents the first complete barrier to the effusion of blood. This coagulum, viewed externally, appears like a continuation of the artery, but on cutting open the artery, its termination can be dis-

tinctly seen with the coagulum completely shutting up its mouth, and inclosed in its sheath.

The mouth of the artery being no longer pervious, nor a collateral branch very near it, the blood just within it is at rest, coagulates, and forms, in general, a slender conical coagulum, which neither fills up the canal of the artery, nor adheres to its sides, except by a small portion of the circumference of its base, which lies near the extremity of the vessel. This coagulum is distinct from the former, and I have called it the internal coagulum.

In the mean time the cut extremity of the artery inflames, and the vasa vasorum pour out lymph, which is prevented from escaping by the external coagulum. This lymph fills up the extremity of the artery, is situated between the internal and external coagula of blood, is somewhat intermingled with them, or adheres to them, and is firmly united all round to the internal coat of the artery.

The permanent suppression of the hemorrhage chiefly depends on this coagulum of lymph; but while it is forming within, the extremity of the artery is farther secured by a gradual contraction which it undergoes, and by an effusion of lymph between its tunics, and into the cellular membrane surrounding it; in consequence of which these parts become thickened, and so completely incorporated with each other, that it is impossible to distinguish one from the other: thus, not only is the canal of the artery obliterated, but its

extremity also is completely effaced, and blended with the surrounding parts.

When the wound in the integuments is not healed by the first intention, coagulating lymph, which is soon effused, not only attaches the artery firmly to the subjacent and lateral parts, but also gives it a new covering,* and completely excludes it from the external wound, which then goes on to fill up and heal in the usual manner.

The circumstances now described are observed also in the inferior portion of the artery, or that, which is supplied with blood by anastomosis; with this difference only, that its orifice is generally more contracted, and the external coagulum is much smaller than the one which adheres to the mouth of the superior portion of the artery, or that from which the blood flows in its direct course from the heart.†

From this view of the subject we can no longer consider the suppression of hemorrhage as a simple or mere mechanical effect, but as a process performed by the concurrent and successive operations of many causes: these may briefly be stated to consist in the retraction and contraction of the artery; the formation of a coagulum at its mouth; the inflammation and consolidation of its extremity by an effusion of coagu-

* See plate III.

† The terms superior and inferior apply only to the extremities: the other distinctions here used must therefore be attended to for the carotids.

lating lymph within its canal, between its tunics and in the cellular substance surrounding it.

And we may conclude that, except in some rare instances, in which the strong retraction and contraction of a divided or lacerated artery prevent hemorrhage altogether, a languid state of the circulation is necessary for the accomplishment of the natural means by which the hemorrhage is stopped. These means may be divided into the *temporary* and *permanent:* under the former head we may include the three first of the above mentioned causes; whilst the effusion of lymph constitutes the permanent: yet even these can be distinctly traced only for a certain time, in consequence of other changes which the artery gradually undergoes. Its obliterated extremity no longer allowing the blood to circulate through it, the portion which lies between it and the first lateral branch is no more distended and excited to action as formerly; but gradually contracts, till at length its cavity is completely obliterated, and its condensed tunics assume a ligamentous appearance. At the same time, the remarkable appearances at the extremity of the artery are undergoing a considerable change; the external coagulum of blood, which in the first instance had stopped the hemorrhage, is absorbed in the course of a few days,* and the coagulating lymph, which had been effused around it, and had produced a thickened and almost cartilaginous appearance in the parts, is gradually removed, and they again appear more or less completely restored to their cellular texture.

* Vide Experiment XIX. plate I. fig. 4.

Nor are these all the changes which the artery undergoes; for, if examined at a still later period, the ligamentous portion is found to be reduced to a filamentous state, distinguishable from the surrounding cellular membrane only by being somewhat coarser; and thus the obstruction which commenced at the extremity of the canal terminates in the complete annihilation of the artery to the first lateral branch.

But long before this final change is accomplished, many of the lateral branches of the superior and inferior portions of the artery have become very much enlarged, and have established by frequent anastomoses a free and ready communication between these disunited parts of the trunk. The small branches by whose immediate inosculation these anastomoses are formed appear to have undergone the principal changes; they are not only proportionably more enlarged than the large branches of the limb to which they belong, and very considerably larger than the corresponding branches of the other limb, but have also become longer, and, being confined within their former space, assume a beautifully tortuous and serpentine course, in order to accommodate themselves to it.

The circulation appears to be carried on as perfectly and vigorously by these anastomosing branches in the limb, the main artery of which has been divided, as in that in which the artery is entire; the inferior part of the divided artery, and all its branches, being found fully equal in size to the corresponding part of the trunk and branches of the artery of the opposite limb which has not been divided: and hence, we may con-

clude, with the celebrated Mr. Hunter, that "Vessels have a power of increase within themselves, "both in diameter and in length, which is according "to the necessity, whether natural or diseased."*

I shall now make some further observations relative to the external and internal coagula of blood, and the intermediate one of lymph, which, if introduced before, would have too much interrupted the detail of the process. And first of the external coagulum—

Its particular figure and extent vary according to the manner in which the wound has been inflicted. If the artery, its sheath, the vein, and nerve accompanying it, have all been completely divided, the figure and extent of the coagulum will depend on the relative retraction of the artery to that of the sheath, which varies in different animals, and according as the artery has been more or less detached from the surrounding cellular substance.

If the *artery alone* be divided, the anterior part of its sheath having been opened longitudinally, the coagulum which then forms at the mouth of the artery varies from a quarter to near half an inch in length, and differs from the form of the artery only in being sometimes slightly conical at its extremity; which, when the integuments have been sewed up previous to the division of the vessel, is turned forward, and is continuous with a large globular portion of coagulum, which being confined by the integu-

* Hunter on the Blood, &c.

ments alone, lies over it and the extremity of the artery. This appearance of the external coagulum may readily be accounted for from the circumstance of the sheath not having been divided so as to admit of its retraction; whereas the complete division of the artery allows it to retract even within the part to which the wound of the sheath has extended, and, accordingly, that portion of the coagulum which lies within the entire part of the sheath, assumes the form of the artery; while the portion of sheath which has been opened, being deprived of the support of the artery, and of its tension, is more or less disposed to collapse, and will necessarily give a conical appearance to the portion of coagulum formed within it; and thus it is that the lower extremity of the external coagulum is sometimes conical: but when the integuments have been sewed up previous to the division of the artery, in consequence of the impediment which that circumstance affords to the exit of the blood, even this flaccid portion of the sheath becomes fully distended with blood, and of course the conical form of the external coagulum is prevented.—I have been thus particular in explaining these circumstances, because I wish it to be clearly understood, how a slight difference in the manner of performing the experiments may occasion a variation in the appearance of the parts when examined; and if, in repeating experiments on this subject, any deviation from the account here given should be observed, I am convinced it will be satisfactorily accounted for, by attending to the manner in which the experiment is performed in both instances.

The extent, and, indeed, even the formation of the *internal* coagulum of blood, depend very much on the distance from a lateral branch, at which the division of the artery has taken place: thus, if it is divided about a quarter of an inch beyond a branch, there will scarcely be formed any coagulum of this description, for the effusion of lymph at the cut extremity of the artery is in general sufficient to form a coagulum which extends a little way within the artery, and then the space between the extremity of the coagulum of lymph and the lateral branch is so short, that no internal coagulum of blood can be formed, at least none worth mentioning. In some instances I have found a small lamina of coagulated blood, not thicker than a six-pence, lying on the coagulum of lymph, the extremity of which in these cases generally projects a little beyond the extremity of the artery, and extends further within its canal than merely the surface by which it adheres; which circumstance seems to depend on a larger quantity of lymph being effused than is necessary to fill up the canal of the artery as far as the inflammation extends on its internal surface, and the superfluous quantity not coming in contact with an inflamed surface, and the blood being constantly driven between it and the sides of the artery, it forms no adhesion, but projects a little within the canal. It is probable that the compression, which the lymph undergoes from the gradual contraction of the extremity of the artery, may also contribute to this effect.

But when the division of an artery has taken place at some distance from a lateral branch, a long conical

internal coagulum is then formed, whose base is situated towards the extremity of the artery, and in general it adheres partially at the circumference of its base to the internal surface of the artery, close to the coagulum of the lymph.

The internal coagulum of blood, however, does not fill up the cavity of the artery throughout the whole of its extent; and though conical, it has often the appearance of not having been formed at once, but by the successive coagulation of small quantities of blood. It is very readily distinguished from the coagulum formed by the effusion of lymph from the inflamed extremity of the artery, which is rather brown than white at first, probably in consequence of some admixture of red particles, and which is *principally characterized by adhering almost throughout its whole extent to the internal surface of the artery:* whereas the former, *i. e.* the internal coagulum of blood, although much longer than this of lymph, forms no adhesion whatever, except a slight one at its base, and which seems to be produced by the coagulum of blood being formed while the lymph is sufficiently recent to allow it to stick to it. Although the internal coagulum of blood when first formed by no means fills up the canal of the artery, except at its base; yet, in consequence of the contraction which the portion of artery containing it gradually undergoes, after a short time it embraces the coagulum so closely that they appear to cohere to each other; so that although the greater part of the coagulum, preserving its natural form, may very easily be separated from the artery, yet its internal surface is left of a

black colour, as if an external lamina of the coagulum still remained on it. It is also highly worthy of notice, that on examining, at a distant period after these experiments, arteries which, (from similar experiments on the corresponding arteries of other animals more speedily examined), we know must have had considerable coagula of blood in them; no coagula should be found in them; but their internal surface is very black, and their external appearance, previous to being cut open, remarkably dark.

From what has been said it appears, that when an artery has been divided at some distance from a lateral branch, three coagula are formed: one of blood, externally, which shuts up its mouth; one of lymph, just within the extremity of its canal; and one of blood, within its cavity, and contiguous to that of lymph.

I have called that of lymph a coagulum, because, when the divided artery has been left entirely to itself, there is such a quantity of lymph effused that, although it is firmly united to the internal surface of the artery, it may be considered as a distinct substance; but, if the cut edges of the extremity of the artery had been kept in contact with each other by pressure, they would have cicatrized, and no coagulum would have been formed; *i. e.* coagulating lymph would not have been effused in such a quantity as to form a mass of a determinate figure.*

* The following passage shows that Petit had also observed this coagulum of lymph as distinct from that of blood, although in

I have already remarked, that when the division of an artery has been made very near to a lateral branch, no internal coagulum of blood is formed: hence we see that the number of coagula varies according to circumstances. But the external coagulum is always formed, and is subject to no other variations than those already described.

The internal coagulum of blood contributes nothing to the suppression of hemorrhage in ordinary accidents, because its formation is uncertain, or when formed it rarely fills the canal of the artery, or, if it fills the canal, does not adhere to the internal coat of the artery. Hitherto, therefore, I have contented myself with noticing its existence, or pointing out the circumstance which prevents its formation, without ranking it amongst the means which nature employs for the suppression of hemorrhage. But if an artery be lacerated, its internal coat will be torn in many places, in proportion to the degree of violence with which the injury has been inflicted. Under this particular accident the internal coagulum of blood may extend beyond many collateral branches, will fill the canal of the artery, and will adhere to its internal surface wherever it is lacerated, in consequence of lymph being effused from these several wounds of the internal

contact, and no doubt adhering to it. After some precautions which he gives to avoid interrupting the formation of a clot, he adds, " Il sera placé favourablement puisque *la partie blanche* qui " est plus legère que la rouge, s'elevera près de l'extremité du " vaisseau, qui est le lieu le plus avantageux que puisse occuper " le caillot." Petit, Mem. &c de l'année 1732.

coat. The internal coagulum may in this case avail against a return of hemorrhage.

Experiments V. and XII. of the Second Section of this chapter show that the peculiar state of the coagulum excepted, the natural means of suppressing hemorrhage were the same in these instances of lacerated arteries as we have found them to be in ordinary wounds of arteries; and which, contrary to what is supposed, will, I think, prove true in general, with respect to lacerated arteries; but I am not solicitous of pressing this opinion at present.

Although I trust that every part of the process which I have now detailed appears to be fairly and satisfactorily deduced from the experiments which were previously related; yet, as experiments on an important practical subject require all the confirmation of which they are susceptible, to intitle them to such confidence as may render them useful, I should but partially accomplish my object, was I not to point out the unquestionable support which the above account derives from observations made on different occasions, and with different views, by eminent surgeons and physiologists. But as nothing can more essentially contribute to establish its validity than an illustration of its perfect conformity with the remarks of almost all who have written professedly on the subject, although they have drawn very different conclusions from them, I shall first take notice of this coincidence.

The circumstances in which the account here given of the process agrees with the doctrines of Petit and

Morand, need not to be pointed out: it has at once confirmed the accuracy of their general conclusions; proved them to be deficient in the series of their observations; and, in fact, differs from them chiefly in being more particular and comprehensive.

With regard to Pouteau's valuable memoir, I shall now bestow on it the attention to which I formerly alluded, and from which I trust it will appear, that however the view which I have given of the subject may differ from his doctrine, it agrees with, and is confirmed by, the facts and observations which he has recorded.

At the commencement of his memoir Mr. Pouteau relates two experiments which had been made on horses, in order to give Mr. La Fosse an opportunity to try the power of lycoperdon in stopping hemorrhages: they are so very applicable to our present purpose, that I trust it will not be considered useless to quote them prètty fully. In the first experiment the fore-leg of a horse was cut off ten inches above the knee; no hemorrhage followed, and of course no inference could be drawn as to the styptic power of the lycoperdon: but the experiment is extremely interesting as an instance of the natural means by which hemorrhage is stopped; for Mr. Pouteau tells us that, "Trois jours après, il n'étoit point survenu d'hémor-"rhagie. On fit tuer l'animal et ayant ouvert la "principalle artère du moignon, suivant sa longueur, "on trouva quatre doigts au dessus de l'artère coupée "un corps de figure conique dont la base étoit fort "adherente, par toute sa circonference, à la tu-

" nique interne de cette artère, et tournée du côté
" opposé à l'extremité tronquée. Ce corps conique
" degorgé dans de l'eau claire, parut très distincte-
" ment un sac quasi membraneux en forme d'enton-
" noir borgne, rempli d'un caillot de sang noirâtre;
" il laissoit voir à la loupe une grande quantité de bour-
" geons, semblables à ceux qui naissent d'une plaie
" qui commence à s'incarner. Au reste toute l'inter-
" valle de l'artère comprise entre l'endroit où le sac
" étoit adherent et l'extremité de l'artère tronqué étoit
" rempli de caillots lymphatiques et sanguins; sans
" ordre ni figure regulière, ayant, cependant, quelques
" legères adhérences avec l'artère."*

A few observations will be sufficient to show the agreement between the appearances here mentioned, and the account which I have given of the natural process of suppressing hemorrhage. It is to be remembered that Pouteau, among his objections to former theories, speaks of the retraction of divided arteries as a thing which had not been proved; consequently he has not availed himself of it in explaining the appearances he observed; but has proceeded on the supposition that the artery preserved the same relative position to the surrounding parts as it had previous to its division; and hence he informs us, that *four fingers breadth above the cut artery, a conical substance was found whose base adhered by its circumference to the internal coat of that artery, and was turned in the opposite direction to its truncated extremity.* But since we are no longer at liberty to doubt of the retraction of divided arteries, and we find that

* Mélanges de Chirurgie, p. 301.

in the instance now under consideration the division was not followed by hemorrhage, we may fairly conclude that the artery must have retracted very forcibly; in consequence of which the extremity of the sheath had been drawn together, so as to form a conical pouch, into which a little blood flowed from the artery; but not being allowed to escape, it coagulated there, and formed the " *caillot noirâtre*," or, " sanguin," and in the course of a short time the extremity of the artery inflamed, and poured out lymph, which formed the " caillot lymphatique," which was found adhering by the whole of its circumference to the internal coat of the artery.

After relating this experiment, Mr. Pouteau informs us, that as it was not considered decisive with regard to the effects of the lycoperdon, a second was instituted, in which the leg of a mare was cut off ten inches above the ham; the blood flowed impetuously, but was stopped by the lycoperdon. " Trois jours après on " ouvrit l'artère crurale suivant sa longueur, et on " observa un caillot formé en cône dont la base regar- " doit l'extremité tronquée de l'artère qu'elle bouchoit " exactement. La pointe tournée du côté opposé " s'allongoit en forme de stilet flottant dans le tuyau " arteriel. La base debordoit d'une ligne ou environ " l'extremité tronquée de l'artère; elle étoit mousse " et arrondie en forme de mamelon et couverte de " bourgeons. La pointe avoit une surface lisse, et " une consistence à peu-pres égale à celle de la tu- " nique interne de l'artère. La partie moyenne qu'on " pouvoit appeller le corps du caillot étoit plus rouge- " atre que les extrémités, elles n'avoient qu'une tein-

"ture presque imperceptible; mais le caillot n'étoit "pas moins ferme et tenoit si fortement à l'artère, "qu'on ne peut l'en détacher sans dechirement."*

In neither of these experiments is there any mention made of the distance between the first lateral branch and the extremity of the artery. In the second experiment, however, we may conclude that there must have been space enough for a coagulum to form within the artery, as, from the description given of the coagulum, it appears to have consisted of lymph which had been effused from the vessels at the extremity of the artery, and of blood which had coagulated within the artery; the former accounts for its adhering so strongly to it that it could not be separated from it without laceration; and for the granulated appearance exhibited by the portion which projected beyond the extremity of the artery; while the latter accounts for the tapering extremity which floated in the arterial canal. With regard to the center of the coagulum being more red than the extremities, that no doubt was owing to the lower portion of the coagulum of blood adhering to the upper portion of the coagulum of lymph; and as the red particles of the coagulum of blood would naturally subside to its lowest part, we can readily understand why the center should have been red, while the extremities were white.

Mr. Gooch and Mr. White rested their opinions upon the experiments of Mr. Pouteau and Mr. Kirkland. In the first section of this chapter I have shown wherein the observations of these gentlemen were defective. In this I have already pointed out the coinci-

* Mélanges de Chirurgie, p. 302.

dence afforded me by Pouteau's experiments. It remains for me to observe, that Mr. Kirkland himself, in treating of the imperfect application of pressure on a divided artery, a view of the subject which nearly corresponds with the natural means of suppressing hemorrhage, is obliged to admit the doctrine of a coagulum, though in so doing he endeavours as much as possible to bring it into disgrace.

He says, "if the fungus, instead of being pressed "close against the end of the vessel, be only laid near "the orifice, it *suppresses the hemorrhage by choking* "*up the mouth of the vessel with coagulated blood*, which "hinders its being closed; and though it stops the "bleeding at present, yet it may be the source of a "future hemorrhage. This is evident* from the ex- "periments made by La Fosse (Phil. Trans. Vol. "XLIX. art. 10 and 11.) where the coagulated "blood, which filled the end of the artery, was formed "into a cone with its apex towards the heart; con- "sequently, if the plug happens to extend to the next "collateral branch, a fresh flux of blood must ensue "upon its coming away; for it does not unite with "the vessel as some have imagined. I know there are "instances, where an orifice made in an artery has "been stopped with a clot of solid blood, which ad- "hering firmly to the cicatrix of the integuments, "produced a considerable callosity, and which seems "to have given rise to this opinion. But it must be "observed in these cases, the wound was cured with- "out coming to suppuration; whereas, when the air

* Not that the coagulum was the source of a future hemorrhage, for no such event happened.

" has free access, we well know a putrefaction of the
" coagulated blood, as well as digestion, is always the
" consequence; and I make no doubt but the separa-
" tion of coagulated blood is one cause why a fresh
" bleeding has sometimes come on after the inflamma-
" tion was abated, and matter began to be discharged.
" In a very late instance, where the bleeding from a
" divided artery had been suppressed by coagulated
" blood, I saw it renewed again next day by taking
" this blood away; the artery bleeding in the same
" manner as when it was first opened, but upon press-
" ing it between my fingers it was soon effectually
" closed. This leads me to take notice of Petit's
" opinion, who imagined that the hemorrhage from
" divided arteries was always suppressed by plugs of
" blood within the vessel, because he found in some of
" them, after the death of the patient, coagulated
" blood, which extended itself upwards a considerable
" way. But notwithstanding this it is very probable
" that the hemorrhage was stopped by the natural
" contraction of the vessel; for we find in the two
" wagoners mentioned by Mr. Faget (Phil. Trans.
" 1753,) where after death, coagulated blood was
" found in the same manner, their extremities were
" contracted and straitened, as if they had been tied;
" and in the many experiments I have made on this
" occasion, I never found coagulated blood but once;
" and then the extremity of the artery was close con-
" tracted. It was," adds he in a note, " in the artery
" of a large dog which was strangled. The horses,
" &c. were killed by being bled to death in the usual
" manner, which seems to prove that the coagula are
" not formed while the blood circulates regularly, but

" when the animal is near dying, or immediately after " death."

" Pouteau opened several arteries, and never found " any coagulum; nor is there any coagulum found in " the umbilical vessels after death. From all which " may we not conclude, that this circumstance is " merely accidental, and no step taken by Nature, " who is always uniform if no impediment is in the " way?"

The positions of Mr. Kirkland—That the clot hinders the artery from being closed, and may be the source of a future hemorrhage—That if it extends to the next collateral branch, a fresh flux of blood must ensue on its coming away—That a putrefaction of the clot is always the consequence of a free access of air, and of the wound coming to suppuration,—are mere opinions, unsupported by his experiments, and contradicted by mine. The very experiments made by La Fosse, to which he appeals in proof of the hemorrhage being suppressed by coagulated blood if the fungus is not pressed close against the end of the vessel, contradict those positions. He is inconsistent when he would explain away what Petit saw, by saying, that, " notwithstanding this (the coagulated " blood within the artery,) it is very probable that " the hemorrhage was stopped by the natural contrac- " tion of the vessel:" for his position above is, that if the fungus be " only laid near the orifice, it sup- " presses the hemorrhage by choking up the mouth " of the vessel with coagulated blood, *which hinders* " *its being closed.*" The two cases related by Mr.

Faget, to which he refers, I shall presently quote, and show that the contraction of the artery was only a part of the process, and, in the degree he mentions, subsequent to the formation of a coagulum. He is mistaken in saying that Pouteau never found any coagulum. I have shown that he found it in the horses on which he made his experiments, when the examination was made in proper time; but looked for it in vain at an advanced period, when other changes had taken place. That Mr. Kirkland should find "coagulated blood" only once, I confess greatly surprises me; but his experiments are before the public, and to this positive assertion I have no answer to offer but an appeal to my experiments, and to the very respectable testimony which I have already brought, and still have to bring, in support of this fact. Mr. Kirkland refers to the 49th vol. of the Phil. Trans. for the experiments of Mr. La Fosse, farrier to the king of France, made upon the principal arteries of horses after being divided, in proof of the very circumstance which he afterwards wishes to be considered as merely accidental; namely, the mouth of the vessel being choked up with coagulated blood, as he expresses it. In proof of this fact—the existence of a coagulum—I beg leave also to refer the reader to the same experiments, and shall only extract from the same volume the conclusions drawn from those experiments, and communicated by Mr. Warner, as from Dr. Latterman to Dr. Schlosser of London.

"Dr. Latterman observes, that the virtues of the "powder of the lycoperdon, or the lupi crepitus, have "been known for some time; but that Mr. La Fosse "has made them more conspicuous by his experi-

"ments." His observations are, "that, upon ap-
"plying it upon the mouths of the divided arteries,
"when divided, the bleeding has ceased in a few mi-
"nutes, and that the mouths of the divided arteries
"have healed up without any farther discharge.
"That in twenty-four hours after the application of
"this powder, a thin pellicle or skin is formed upon
"the mouths of the divided arteries, and that within
"the vessel is found a small plug of congealed blood.
"That the pulsation of the artery is to be seen in a
"very distinct manner at the extremities of the ves-
"sels. That the coagulated blood is of a conical
"figure, whose basis is at the mouth of the vessel,
"and its apex in an opposite direction," *i. e.* inward.
"Dr. L. says, that all these curious experiments
"have been verified by the commissaries of the
"academy of sciences, who upon observation have
"found them all agreeable to truth." The coinci-
dence between these experiments and mine of the existence and figure of the internal coagulum of blood is quite manifest. The distinction of the external coagulum of blood is not made, but I think the coagulum of lymph is described where it is said, that in twenty-four hours a thin pellicle or skin is formed upon the mouths of the divided arteries. I have before said that the external coagulum of blood is always formed where the divided artery is left to nature; not so, however, if art interferes, for under the application of the ligature it can never form. If agaric, lycoperdon, or sponge, be used, its formation is doubtful, depending entirely upon the degree of pressure that is used, for these artificial modes are in place of the external coagulum; but the internal coa-

gulum of blood will be equally formed, whether the treatment be left to art or nature, if no collateral branch is near the truncated extremity of the artery; and lastly, effused lymph, which, when in sufficient quantity, forms a distinct coagulum just at the mouth of the artery, will be always found, if the hemorrhage is permanently suppressed.

The coincidence must in similar comparisons be received as to the mere existence of the coagulum without reference to its distinct parts, for only Petit, as far as I know, has noticed, that part of the coagulum of blood is external to the artery, and part internal, calling them by the distinct names of "couvercle" and "bouchon;" but the latter term, according to my experiments, conveys a false idea, attaching an importance to the internal coagulum that is not due to it.

Mr. Kirkland appeals to the cases of two wagoners that are related in Mr. Faget's remarks on the use of agaric, as making it very probable that hemorrhage is stopped by contraction of the artery even in those cases in which a coagulum is found. It is sufficient to premise, that after amputation hemorrhage was prevented by confining pieces of agaric over the arteries, and that one of the men died on the fifth day, the other on the ninth, but there had not been the least tendency to hemorrhage. Let us be more particular in the report of the dissection. "I examined the "blood-vessels of those two patients after their death, "and I found them contracted and straitened, as if "they had been tied, and in the largest of them a "conic coagulation of the blood, which was an inch

" and a half long; and after having taken out this coa-
" gulation, it was with difficulty that I could intro-
" duce the point of a very small probe into the orifice
" of that vessel.

" The patient who died on the ninth day, had the
" arteries contracted in the same manner; but with
" this difference, that the congelation was at least four
" inches long." Warner's Cases in Surgery.

I request the reader will refer to Experiment XIX. in the second section of this Chapter, illustrated by Plate I. Fig. 4. The examination in this experiment happened to be on the 9th day, and the coincidence between this and Mr. Faget's cases is very striking, especially when compared with some of my earliest experiments, by a consideration of which it will be manifest, that the *great* contraction noticed in Mr. Faget's case and my experiment of the 9th day, was that *subsequent* gradual change of the artery tending to obliteration, which I have already described.

In justice to the accuracy of Messrs. Petit and Morand, as well as to point out the exact agreement between their observations on the human subject, and those which have been made in the course of these experiments on brutes, I have great pleasure in giving the following interesting quotations, relating to the permanent means of suppressing hemorrhage by the effusion of lymph, or the formation of a coagulum of lymph.

Petit, after observing that he prefers clots formed by the spontaneous coagulation of the blood, without the addition of caustic, styptics, or astringents; and after entering into a particular detail of the phenomena of coagulation, and noticing the greater firmness of coagula when they consist of lymph alone, than when they are in part formed of red globules, very judiciously adds, "Le Caillot de la seule lymphe est " donc plus ferme, et par consequent plus durable " que celui de la partie rouge et de la partie blanche " mêlées ensemble; et *il est donc plus avantageux que le* " *caillot qui arrête le sang soit fait de la partie blanche* " *seule, que s'il est fait de l'une et l'autre mêlées ensem-* " *ble.*" Petit, Mémoires de l'Acad. Roy. des Sciences.

" Après toutes les observations que j'ai faites sur " la manière dont s'arrête l'hemorrhagie, je n'ai pû " m'empêcher de considerer *le Caillot comme un Corps* " *formé de l'assemblage des parties du sang qui sont* " *destinées à la nouriture et à la reparation des parties,* " *c'est à dire, de cette substance que s'épanche dans les* " *plaies, et qui les réunit en quatre ou cinq heures, si* " *on a eu soin d'en rapprocher les bords. Ce qu'il y a de* " *certain c'est que nous trouvons ce Caillot aussi forte-* " *ment attaché au bord de l'ouverture de l'artère que les* " *chairs qui forment les cicatrices, le sont aux levres des* " *plaies.* Je ne prétends pas prouver ici que l'orga- " nization de ce Caillot soit précisement la même que " celle des chairs, qui se régénèrent dans les plaies, " et qui forment leur cicatrices; mais aussi on auroit " bien de la peine à prouver le contraire. Je laisse " à part cette discussion, il suffit d'être assuré *que ce* " *caillot ou cette portion de suc nourricier épaissie étant*

" *une fois intimement unie à l'ouverture ou coupure de* " *l'artère non seulement empêche le sang de sortir pen-* " *dant la cure de la maladie*, mais encore qu'elle reste " après la guérison, et qu'elle ne diminue que comme " les cicatrices diminuent, je veux dire, à mésure " qu'elles affermissent." Petit, Mem. de l'Acad. &c. " de l'année 1735, 8vo. edit. p. 598-9.

" La Reflection fait voir que dans tous ces états, le " Caillot prend la forme que l'artère lui a donnée, qu'il " faut toujours admettre le concours du vaisseau avec " le Caillot pour arrêter l'hemorrhagie, et que si le " Caillot peut pendant quelque tems suspendre le " rétour de l'hemorrhagie, *c'est l'artère même cica-* " *trisée qui doit l'empêcher pour toujours.*" Morand, Mem. de l'Acad. des Sciences de l'année 1736, 8vo. edit. p. 446.

The fact alluded to in these quotations appears also to be confirmed by the observations of Mr. Gooch. " It appears to me highly reasonable to suppose, that " the native heat of the part, and the action of the " vessels, keep the blood in a state of fluidity, fit to be " received by the collateral branches, when checked " by natural or artificial means in its direct progressive " course after amputation of the limb, and that the " divided vessels then retracting, collapse and coalesce " as far as their first ramifications, *having their mouths* " *soon sealed up with flesh growing from the nutritious* " *vessels*, which work of nature is pretty evident upon " the stump." Gooch's Cases and Practical Remarks in Surgery.

On the same subject I find the following experiment by Haller. Venam grandem totam dissecui. Pars intestino proprior non dedit sanguinem: pars vero cordi continua utique. Arteriam laceravi, ut expirer, num aliter lacerata se haberet quam incisa. Pars ea, quæ intestino proprior, eadem nullum sanguinem suppeditavit: à corde vero plurimus advenit, et modo pleno flumine erupit, modo coarctato, ut columna sanguinis conicam figuram exprimeret. Accurate examinato phænomeno adparuit, invisibilem liquorem partem luminis arteriosi tenuisse, eo majorem, quo proprior fuit vulneri, ut pro eâdem portione, sanguinea columna angustior foret. *Nam rasâ et abstersâ arteriâ* torrens sanguinis cylindri plenam figuram recuperavit. Denique perinde hæmorrhagiæ finis factus est, *ut alba nebula rubro cum centro*, vas extremum clauderet.*

I have diligently sought in periodical and other records of surgery for cases of divided arteries in the human subject, to illustrate and confirm the doctrine of the natural means of suppressing hemorrhage as deduced from my experiments; but I have been mortified at finding those records so barren of these important cases, and disappointed at the imperfect detail of the few that are before the public. I have especially to regret the total want of observation of the condition of the artery itself, even where the opportunity of ascertaining it had offered. Four or five remarkable cases of limbs torn off without hemorrhage, even from the largest arteries, are recorded, but afford us not the least instruction as to the means by which the hemor-

* Haller, Op. Minor. tom. i. sect. vii. p. 109, 110.

rhage was prevented, because the artery was not examined. It is too much to assert that it was prevented by contraction of the artery. We have no proof of the fact. On the contrary experiments 5th and 12th of the 2d section of this chapter show, that it is by no means the necessary consequence of a lacerated artery that it should not bleed even as freely as after simple division of the artery. The difference between my experiments and these cases consists in this, that in the former the artery was lacerated by a sudden and forcible extension of it; in the latter by violent and repeated contortions not only of the artery but of the surrounding parts. This very difference would afford me a plausible solution of the difficulty, yet it would still be but conjecture, which ought not to usurp the place of fact. One case of laceration and two of simple division of large arteries, in which the suppression of the hemorrhage was wholly natural, the reader will not be displeased that I quote at large, since the judicious interference of art, which is so eagerly sought after on these alarming occasions, can seldom allow us to see in the human subject what unassisted nature can effect. I regret, that the opportunity which offered, in one of these cases to ascertain the precise state of the artery, was neglected; but as far as this case and the others are detailed, they contradict none of the observations that experiments on brutes have afforded me; and with these cases I shall conclude this part of my subject.

The first case that I shall quote is from Van Swieten's Commentaries,* and which he says Boerhaave usually related to his audience.

* Translated from the Latin. Vol. II.

" A countryman was wounded with a knife in the " arm-pit, so as to divide the axillary artery; whence " the blood followed with an incredible velocity, and " he falling down soon after, was believed and laid out " to be dead: but on the next day, when those who " were appointed by public authority came to examine " his body, that they might make a report concerning " the mortality of this wound to the proper judges, " they then found that there was some warmth still " remaining about his thorax, without any other signs " of life; and therefore they deferred the examination " of the wound for some hours; during which time " the wounded person, who every one imagined would " totally expire, shortly began sensibly to recover " himself; so that notwithstanding his continuing so " long in such a very low, weak, and almost lifeless " state, he recovered, beyond the expectation of every " one."

This case affords us the important fact, that the axillary artery, even of the human subject, may be divided, and yet the hemorrhage be suppressed by the natural means; but who would dare to risk this balance between life and death! Compare Experiments III. VI. and XI. and it will not be too much to repeat what I said at the conclusion of the sixth, that when very large arteries are divided, and the pressure of the integuments is taken off, the external coagulum must, in general, form too late to prevent the animal from being exhausted.

The second case is from Gooch.* His patient, when very drunk, was thrown out of a cart. "The wheel "of the cart passed over the top of his arm and shoul- "der, contusing those parts very much, quite to his "neck; and at this juncture an iron hook, belonging "to the cart, entered between the biceps and coraco- "brachialis, making a large lacerated wound, includ- "ing the fasciculus of nerves which take that course. "The limb was wholly deprived of sensation and mo- "tion; and, finding no pulsation at the wrist, we "concluded the brachial artery was divided; but the "*hemorrhage, which at first was very profuse*, was "stopped by the retraction of the vessel, and having "the arm confined to the side." The arm mortified, and the patient died in forty eight hours. Next morning he examined the limb, and "found the artery "quite divided, having the superior end retracted "into the axilla, and separated more than an inch "from the inferior." This, to my regret, is all the examination he made with respect to the artery. Notwithstanding the laceration of the artery, we are informed, that the hemorrhage was at first very profuse. This case may be compared with Experiment V. and XII. of the Second Section of this Chapter.

The last case I shall abstract is from Garengeot, of a sword-cutler, who was wounded with a broadsword "sur la partie antérieure du poignet, de sorte que "son articulation en fut à moitié ouverte, un des ten- "dons extenseurs du pouce coupé; l'artère radiale, "je veux dire celle qu'on tate pour sentir le poul fut

* Gooch's Surgery, Vol. I.

" coupée, aussi bien que le tendon du muscle radiale
" interne. Enfin ce coup d'espadron avoit si bien
" ouvert la partie antérieure et interne de l'articula-
" tion du poignet droit que devenue béante par le
" poids de la main, elle eût pû y recevoir un œuf."

As some time was required to prepare a needle and ligature, he placed the hand so that the lips of the wound might be in contact, and made his boy hold it in that position, while he made ready the things which he required; and says, " Je me disposai d'abord à
" lier l'artère radiale: or pour appercevoir le sang
" sautiller de cette artère, je saisis l'avant bras du blessé
" avec ma main gauche, et avec la droit, j'empoignai
" ses doigts que j'avois fait tenir par mon garçon; j'ou-
" vris ensuite cette place en baissant la main pour ap-
" percevoir l'endroit d'où le sang s'élançoit avec tant
" de violence: *mais je ne fut jamais plus surpris, que*
" *lorsque je vis le sang arreté.* Alors je dis que la Nature
" plus sage, nous apprenoit le vrai moyen d'arreter
" l'hémorrhagie, et nous fournissoit de grands sujets
" de reflection." Accordingly he only placed the lips of the wound in contact, applied pledgets sprinkled with Bol. Armen: and over them compresses and bandages; and, to moderate the motion of the blood, he applied a longitudinal compress along the inside of the arm, which he put into a sling; bled the patient the next day; kept him on an antiphlogistic regimen; and concludes with saying: " Enfin le douzième jour
" le blessé fut entièrement guèri, et n'a eu depuis ce
" tems-là aucune incommodité à son poignet."*

* Garengeot, Traité des Operat. &c. p. 373, et seq. It may be observed, that Garengeot does not relate this fact to support any

The operation of amputation à lambeau must also have afforded many instances of the suppression of hemorrhage in the human subject by the natural means aided only by gentle pressure;* for we find it mentioned as one of the principal advantages of that operation, that the application of a ligature on the arteries is avoided by it; and Mons. de la Faye, in his memoir on that operation, after enumerating the advantages which had been imputed to it, says: "De ces "six avantages dont je viens de faire l'enumeration, "je n'en reconnois que quatre veritables; sçavoir, la "promptitude de la guérison, à cause que l'exfolia- "tion des os ne se fait point; la facilité d'appliquer "une jambe de bois; *l'inutilité de la ligature et des "astringents aux quels le lambeau supplée.*"†

And Garengeot speaking of this operation, says, "C'est dans cette sorte d'amputation où le tourniquet "est très utile, *puisque les vaisseaux ne sont pas liés, "et n'ont pour empêcher le sang de s'epancher que la "compression du lambeau*, compression qui est infi- "niment au dessus de tous les autres moyens comme "nous l'avons vû dans l'article précédent," *i. e.* in the case which has been just quoted from him.

particular opinion which he had with regard to the natural means by which hemorrhage is suppressed; it is a mere digression in his chapter on Amputation; and, from the manner in which he speaks of it, it is evident that he had nothing more in view than simply to detail the fact, and avail himself of the practical inferences to be drawn from it: thus he says, "Cette expérience que le hasard "m'a fourni plutôt que l'habilité et la reflection, m'a beaucoup "servi dans la pratique de la Chirurgie." Ibid.

* See note B.

† Mem. de l'Acad. de la Chirurgie, 8vo edit. vol. V. p. 213.

All the quotations that appear in this section are to be considered solely in reference to the natural means of suppressing hemorrhage; for at present nature is my theme, and not art. Let not then my silence, as to the practical opinions advanced in these quotations, be misunderstood into an acquiescence with them. When I undertake to show the principle on which the ligature acts, it will be quite manifest, that, in every case admitting of its application, it is abundantly superior to every other means which art can use to bring the artery into that precise condition, under which the natural process, that effects the permanent suppression of hemorrhage, can most certainly, most speedily, and most securely, take place.

CHAPTER II.

ON THE MEANS WHICH NATURE EMPLOYS FOR SUPPRESSING THE HEMORRHAGE FROM PUNCTURED OR PARTIALLY DIVIDED ARTERIES; AND ON THE PROCESS OF REPARATION WHICH TAKES PLACE IN THOSE ARTERIES.

SECTION I.

IT appears to have been a fact soon established in surgery, that the suppression of hemorrhage by the natural means is much more readily and effectually accomplished, when an artery is completely divided, than when it is merely punctured or partially divided; for a complete division of a wounded artery was one of the means used by the ancients* to put an end to the hemorrhage from it.

Having already considered that state of a bleeding artery which appears the most simple, or the process which nature employs for suppressing the hemorrhage

* See Note B.

from divided arteries, I shall now consider the process as it is performed in the case of punctured or partially divided arteries, and also the process of reparation which takes place in those arteries.

The re-union of a wounded artery is an event which I had been so little accustomed to think probable, and the danger of attempting its re-union seemed to be so well established by many terrifying facts from practical authors, that I very much doubt whether I should ever have made any experiments to render them more convincing to myself. The following experiments were originally instituted, chiefly with a view of ascertaining the manner in which an aneurism is formed, when produced by a puncture or wound.

EXPERIMENT I.

I laid bare the carotid artery of a horse with as little injury to its sheath as possible, passed a piece of twine under it, sewed up the integuments, drew out the artery between two of the sutures by means of the twine, and made a longitudinal wound in it with a lancet, and, immediately withdrawing the twine, allowed the artery to return to its place. The animal had not lost more than two pounds of blood, at a very moderate rate, when the hemorrhage ceased completely. He was killed in the usual manner by the slaughterer.

On examining the parts immediately after death, I found a small quantity of coagulated blood between the integuments and muscles; and next to this, a circumscribed portion of coagulated blood over the part of the artery which had been operated on, nearly surrounded by a portion of loose lymph, which appeared to have been separated from the red particles of the blood in the usual manner. On dissecting off a portion of muscle which lay over the artery, I found its sheath filled, to some distance above and below the wounded part, with coagulated blood, which was almost completely confined between the artery and its sheath, the surrounding cellular membrane having scarcely any in it. That part of the sheath through which the artery had been wounded, seemed rather more distended, and was more prominent than any other part; but no wound could be traced in it. See plate IV. fig. 1.

On cutting open the artery at its posterior part, the circumscribed appearance of the effused blood between the artery and its sheath was particularly remarkable. The wound was seen a little below a collateral branch, having its edges red and in perfect contact: it also appeared very much smaller than I expected, considering the extent to which I had passed the lancet. It was probably owing to the smallness of the wound in the artery, and the very slow escape of the blood, that its extravasation was so completely confined to the sheath of the artery, particularly as, from its situation, it found a ready passage through the wound in the integuments. See plate IV. fig. 2.

EXPERIMENT II.

A very small incision being made through the integuments, immediately over the carotid artery of a horse, it was continued directly down to the artery, in as narrow a space as possible. As soon as the sheath of the artery appeared, I introduced my finger into the wound, and keeping it on the artery, passed a lancet down by the side of it, and made an oblique wound, approaching nearer to a transverse than longitudinal direction, through the sheath and artery; the blood immediately flowed in a full stream, and I proceeded to sew up the external wound, which was soon accomplished, as it was very small. The horse was very restless, turning his head in various directions, which accelerated and kept up the hemorrhage with different degrees of rapidity for a great length of time. An hour after the operation the blood still continued to trickle down his neck very rapidly. At length however the hemorrhage ceased, and the animal was allowed to live twenty-four hours after the experiment. On examining the parts, we found a small coagulum of blood between the integuments and muscles. There was a considerable effusion of blood in the cellular membrane between the muscles, and in that which surrounded the artery. On the external surface of the artery, from the posterior point of the wound which had been made in it, there was a rounded column of lymph of a brown colour, which not only completely covered the wound in the artery, but some space around it, and, extending upwards from the artery,

formed the surface of the external wound. The column of lymph was surrounded on all sides by cellular membrane filled with black coagulated blood. The center of its surface had a dark appearance, about two lines in breadth and one third of an inch long. See plate V. fig. 1.

On cutting open the artery at its posterior part, we found its sheath very much distended with lymph, for the space of more than an inch by the side of the wound in the artery. The wound appeared to have been made just below a collateral branch, and to be nearly of a semilunar form; its edges were united by an intervening portion of lymph, which not only adhered to them, but seemed to have been effused from them, and did not project within the canal of the artery so as to interfere with the passage of the blood through it. See plate V. fig. 2.

EXPERIMENT III.

The brachial artery of a stout dog was laid bare as high up as it could be got at, an aneurism needle passed under it, and the external wound sewed up. A needle was then passed through the artery so as to take up about one third of it, which portion being cut through with a scalpel, the aneurism needle was withdrawn, and the artery allowed to resume its former situation. A very profuse hemorrhage followed, but soon ceased after the integuments became distended with blood.

The dog was killed and examined forty hours after the operation. The integuments remained closed by the sutures, but were much distended, and on cutting them open, the wound was found to be full of coagulated blood, with which the cellular membrane connecting the contiguous muscles was also filled. On removing the blood from the wound, we found that its surface was formed by a thick layer of smooth lymph, which completely covered the artery. On cutting open the posterior part of the artery, the wound was distinctly seen plugged up with lymph, which adhered all round to its edges, projected a little within the canal of the vessel, and was gradually lost externally in the surrounding lymph. The artery was a little contracted at the wounded part.

EXPERIMENT IV.

I made an incision over the humeral artery of a horse as high up as I could get at it,* taking care not to open its sheath; and as soon as I could fairly feel the artery, I sewed up the external wound, which was rather extensive, passed my finger into the wound between two of the sutures, and kept it on the artery until I had passed a lancet, and made a considerable wound in it. The blood flowed in so large a stream that I conceived it impossible the

* This was the only horse that would allow me to perform on his humeral artery; with almost all the others I lost much time in making the attempt, and with some of them found it very dangerous.

animal could live long. After it had continued to flow thus profusely for nearly ten minutes, I found that the integuments afforded but little resistance to the escape of the blood, in consequence of the principal sutures being placed at a great distance from each other to allow of my getting at the vessel after the wound was sewed up. I was induced to compensate for the effect, which the integuments properly sewed up would have had, by applying a piece of coarse cloth over the wound, and once round the limb: it was the only thing at hand, and was not large enough to pass oftener round the limb. The blood however continued to flow, though in a diminished stream, and after some time I left the animal bleeding. The day following I was certainly astonished to find the horse alive, eating sparingly, but excessively thirsty. He went on very well, having no return of hemorrhage; and five days after the experiment had been performed, he was killed in the usual manner. On laying open the wound, a small quantity of pus and some coagulated blood were found in it; its surface was formed by a very thick layer of coagulated lymph, which had a granulated appearance, and completely excluded the artery from the external wound. See plate VI.

On cutting open the artery at its posterior part, the cellular membrane surrounding the wounded part was filled and indurated with effused lymph. Within the canal of the artery there was also a very considerable and extensive effusion of lymph, which however did not appear to have obstructed it completely, because there was no coagulum of blood formed on either side

of the lymph, although there was no collateral branch to interfere with its formation; and a probe passed very readily between one of the septa of the lymph, and the artery. See plate VII.

EXPERIMENT V.

I exposed about an inch and a half of the carotid artery of a dog, and, proceeding as in Experiment I. made an oblique wound in it; the blood flowed very freely for some time, but at length a thrombus formed, and the hemorrhage ceased. The day following I found that the animal had got the sutures out of the integuments, and the wound was completely open.

Eight days after the experiment the animal was killed; and the wounded carotid injected from the aorta. The external wound was still open, and its cavity large enough to receive a full sized Spanish chesnut. The surface of its cavity was formed by a smooth vascular layer of lymph, lubricated with very glutinous pus, and having rather a dark appearance just over that part of the artery which had been wounded, probably in consequence of some blood which had been effused at the time of the experiment; or the effused lymph may have been mixed with some of the blood which lay about the part. The artery was so completely covered with the lymph that it could not be seen in the wound. See plate VIII. fig. 1.

On examining the posterior part of the artery, the injection was found to have passed completely and uni-

formly through every part of its canal, without appearing to have met with any obstruction. On each side of the wounded part of the artery, and to some extent above and below, there was a considerable effusion of lymph, which nearly covered its posterior surface, and adhered firmly to its sides. See plate VIII. fig. 2.

EXPERIMENT VI.

The carotid artery of a dog was laid bare, and a longitudinal wound made in it with a lancet, without removing it at all from its situation or surrounding attachments; a profuse hemorrhage followed; the integuments were sewed up as quickly as possible, and soon after they were found distended with blood, and the hemorrhage ceased.

Nine days after this experiment the animal was killed, and on examining the parts, the external wound was found to be very nearly healed. Its surface was formed by a vascular layer of lymph. The artery was injected from the aorta, and the injection passed very readily through it. As it had been wounded anteriorly, I cut open its posterior part, immediately opposite to the wound. The canal of the artery, and the injection, were very slightly narrowed just at this part; the coats of the artery, and the surrounding cellular membrane, were very much thickened. On picking away the portion of injection which passed through this part of the artery, the longitudinal wound was seen to be completely cicatrized. There was a

collateral branch filled with injection on one side of it, and on the other a very thin lamina of lymph adhering to the internal surface of the artery. See plate V. fig. 3.

EXPERIMENT VII.

The femoral artery of a dog was exposed, and a considerable transverse wound made in it with a scalpel; a rapid and profuse hemorrhage immediately followed, and the external wound was sewed up as speedily as possible. In this instance also the artery was not drawn out of its situation, nor detached from the surrounding parts.

Eleven days after the experiment, the animal was killed. The external wound was almost healed. On dilating the integuments, I found the wound filled with lymph, which had a very vascular appearance. On cutting through this lymph I found it very thick, hard, and firmly attached to the artery to a considerable extent. The artery had been injected, and the injection appeared to pass very readily through it. On cutting open the posterior part of the artery, there appeared a band of lymph, adhering firmly to its internal surface, and extending almost round it: there was a very small space which was free from it; but in the entire state of the artery this space must have been so close to the coagulum as to have allowed very little, if any, blood to pass between them. From the center of this transverse band or coagulum

of lymph, there was a small conical portion projecting in the upper part of the canal, and a long irregular tapering portion hanging in the inferior part of it. It also appeared that the wound had been made just above a small collateral branch. All the collateral branches were filled with injection, a thread-like portion of which had insinuated itself between the coagulum and the side of the artery at the above mentioned point; but it appears much more probable that the collateral branches below the coagulum were filled by anastomosis than by this extremely small channel. The cellular membrane on each side of the wounded artery was very much thickened with lymph. See plate V. fig. 4.

The hemorrhage produced from the artery of this dog was so profuse as to render him extremely faint, and reduce his strength very much; at least I conclude so, from not having observed him move his hind legs for three days. When his food was carried to him he raised himself on his fore-legs, ate it, and lay down again. It was probably owing to this circumstance, that he never had any return of hemorrhage; for the wound was certainly large enough to afford reason to expect it.

EXPERIMENT VIII.

The carotid artery of a dog being exposed, and treated as in Experiment I. a moderate transverse wound was made in it with a scalpel; the wound immediately assumed a circular appearance, and the

blood flowed very freely from it; but after a short time the integuments became distended with blood, and the hemorrhage ceased. Eighteen days after the experiment the animal was killed. The external wound was completely healed, and a hard lump was felt under them. On cutting through the integuments, we found a circumscribed, hard, oviform, portion of coagulated blood, lying immediately over the wounded part of the artery, and confined by a cyst which adhered to it and the surrounding parts: the par vagum was turned out of its direct and natural course: the other parts about this mass had a perfectly natural appearance. See plate IV. fig. 3.

On cutting open the posterior part of the artery, its canal was found completely pervious throughout. The wound in the artery preserved its original circular appearance, and was covered with the portion of coagulated blood before noticed. This coagulum adhered slightly to the edges of the wound in the artery, but not at all to the cyst that contained it; neither did it fill up the wound so as to be on a level with the internal surface of the artery. See plate IV. fig. 4.

EXPERIMENT IX.

I laid bare the femoral artery of a dog, and made a very considerable oblique wound in it, proceeding as in Experiment III. A very profuse hemorrhage ensued, but it ceased after the animal had become extremely faint. During the remainder of this and the following day, he lay continually in one place, raising

only his fore legs when his food was carried to him; and during this period he had no return of hemorrhage. But on the following morning he began to move about and seemed very sprightly; and on visiting him a few hours after I found the wound bleeding very rapidly. There can be little doubt that this hemorrhage was brought on by his exertions. In a very short time he appeared extremely languid, and would neither eat nor drink. Some hours after, I found him lying in the same position, and very much daubed with blood; a sure sign of extreme debility, as these animals always lick away the blood which flows, as long as they are able.

The day following he bled again, after which tremor came on, and he died eighty hours after the experiment had been performed.

Dissection. The integuments were still closed by the sutures, and the wound contained a very large quantity of coagulated blood. The cellular membrane between the muscles throughout the limb was filled with blood. On removing the coagulated blood from the wound, we found its surface formed by a thick layer of lymph, at the superior part of which there appeared a little mammillary projection, and just under it the lymph was cracked. On laying bare the posterior part of the vessel, we found a considerable effusion of lymph between it and its sheath to the extent of at least an inch. On cutting open the artery at the back part, the wound which had been made in it was seen to be entirely healed, except at one point; it was of an irregular, somewhat curved figure, and had a dark

red gelatinous appearance: through the part which was not united, or which probably had been torn asunder after having been united, a bristle could readily be passed, and it made its appearance in the cavity of the external wound, immediately under the little mammillary process, and through the aperture already described. The coats of the artery were very much thickened about the wounded part.

EXPERIMENT X.

The brachial artery of a dog was cut through, in the usual manner, as high up as it could be got at, and to the extent of nearly half its circumference. The artery bled very profusely for some time, but the animal becoming extremely faint, and the integuments distended with blood, it at length ceased; the day following, however, it returned in consequence of his moving about; it returned also twice after this; and on the beginning of the sixth day after the experiment he died of hemorrhage. On examining the parts, the sutures were found in the integuments, which were distended with a large clot of blood; on removing this we found a surface formed of a thick vascular layer of lymph. At the bottom of the cavity of the wound there appeared a small projecting mammillary process, detached from the rest of the surface of the wound almost all round its circumference. On cutting open the posteriorpart of the artery, a large and almost circular opening was seen in it; in short, the internal aperture corresponded exactly with that which had been observed externally round the mammillary process.

The internal edges of the wound were very distant from each other, but they were covered with lymph, and seemed to have been torn from the sides of the mammillary process except at one point, at which the adhesion was still complete, and the internal surface of the process corresponded exactly with the center of the wound. From the appearances in this dissection there could be no doubt that the reparation of the wound in the artery was going on in the usual way, but in consequence of some exertion while the lymph was yet in a delicate and tender state, it had been torn through, and had afforded an outlet for the secondary hemorrhages which ensued.

EXPERIMENT XI.

Half the circumference of the femoral artery of a dog was divided in the manner related in Experiment III; the blood flowed from it in a large and rapid stream, which after some time ceased, but left the animal extremely languid. He was so sullen, indeed even ferocious, that I could not examine him properly every day, but I frequently observed small quantities of fresh blood in his kennel.

Four days after the experiment I had him out, but this, although done without any struggling by the man who managed him for me, immediately produced a return of hemorrhage, which however, by allowing him to remain quiet, was soon stopped. On the 5th and 6th days I again observed a little fresh blood on the straw in his kennel; but he kept himself extremely

still, lying almost constantly in the same place; and I never afterwards observed any other sign of a return of hemorrhage.

Twenty-two days after this experiment, he died in consequence of another which I had performed on him. On examination we found the integuments adhering to the subjacent parts, and the external wound about the size of a common pea-issue, and covered with a dark purulent matter. On wiping away the discharge I found that more could be pressed out; and on examining carefully, a sinus appeared, extending from the wound down to the artery. The sinus was lined with coagulable lymph, and on dilating the wound, which had been very deep, it appeared to have been filled up with lymph, which covered the artery and adhered firmly to it. After dissecting out the artery with a considerable portion of the surrounding parts, and laying bare its posterior part, a bristle was passed into the upper part; and after putting it in different directions without using any force it was at last seen at the bottom of the sinus. It was then introduced into the inferior part of the artery, but I could not detect any communication between it and the sinus. The integuments, &c. being then carefully dissected from the anterior part of the artery, it was immediately very evident that the artery was separated into two portions, the extremities of which were at least half an inch distant from each other. On passing the bristle again into the upper portion of the artery, I was able to discover a *very small* space, at which the artery did not adhere to an irregularly formed coagulum that was turned a little on one side,

but lay about two lines' breadth within the mouth of the vessel, and projected about four lines beyond it.

The extremity of the inferior portion of the artery was strongly contracted around a white coagulum, which adhered firmly to its internal surface. Within the cavity of this portion of the artery there was a cylindrical coagulum of blood, which did not adhere to any part of the internal surface of the vessel, but was attached to the white coagulum that shut up its mouth; and a line of distinction between these coagula was evident at the point of their union. There was a considerable quantity of lymph effused by the sides of each portion of the artery, and its surface was remarkably uneven. See plate IX.

EXPERIMENT XII.

The femoral artery of a large dog was cut through in the usual manner, to the extent of fully half its circumference, the external wound having been first sewed up. A very considerable hemorrhage ensued, but, after producing the usual effects, it ceased. The animal lay very quiet for three days, during which I had no opportunity of observing any signs of hemorrhage; but when I visited him, I almost always found him licking the wound, which appeared to be much distended with blood. On the fourth day I found him standing up, and fresh blood was dropping from the wound. The day following I noticed that he had pulled away the sutures, three coagula of blood were found in the vessel in which his food had been given

to him, a small quantity of recent blood was observed on his straw, and blood was slowly trickling over his wound.

On the twelfth day I had him taken out to examine the wound particularly; and in doing this a small coagulum of blood which it contained, for the wound was very deep, was forced out, and the blood immediately followed, but by no means rapidly; by allowing him to remain quiet, it soon ceased.

On the fourteenth day, hemorrhage was again brought on by merely allowing him to walk gently out of his kennel.

On the nineteenth day, slight hemorrhage was twice brought on by the same exertion as on the fourteenth.

Twenty-fourth day. Between this and the nineteenth slight hemorrhage had frequently been induced, by allowing him to walk about the yard. For several days previous to the twenty-fourth I had observed the mouth of the wound very much contracted, and a large black coagulum within its cavity. Slight hemorrhage was brought on again on this day by allowing him to walk about; and in the evening, in consequence of an extraordinary exertion which he made to run up a few steps, two coagula, one very large, were expelled from the wound; profuse and repeated hemorrhages followed their expulsion, and he died in the afternoon of the day following, which was the twenty-fifth after the experiment.

On examining the wound, I found it filled with a recent coagulum of blood, of the size of a hen's egg. On turning out this clot the surface of the wound, consisting of a thick layer of vascular lymph, came into view. At the upper and lower part of it there were two small coagula of blood still sticking on it; and on many parts of it there were several small pendulous portions of lymph, two of which, at the upper part, were very remarkable; one projected considerably in the wound, and had an irregular surface, while the other surrounded about half of its circumference, and had a semilunar figure and smooth surface, but did not adhere to the former. Pressure being made over the superior part of the artery, a small quantity of fluid blood issued from the wound, and just between the two coagula described at its upper part. A bristle being passed into the artery, just under Poupart's ligament, made its appearance within the wound, through the same orifice from which the blood had flowed. On exposing the posterior part of the artery, it was evidently separated into two distinct portions, connected to each other by a band of lymph extending from the extremity of one portion to the other: this band had no doubt been formed by lymph effused into the posterior part of the sheath. On cutting open the superior portion of the artery, we found that it was gradually more and more contracted, as we approached its extremity, and that its mouth was in some degree shut up by a small white coagulum, which adhered very firmly to its internal surface. Between this coagulum and the anterior parietes of the artery, the head of a very small probe was passed, and

then appeared in the external wound under the semi-lunar band of lymph. In this portion of the artery I observed, for the first and only time, a small longitudinal fold on its internal surface, extending from the extremity about an inch up the canal of the vessel, and resembling what Morand has delineated, and called the "froncement" of the artery; with this difference, however, that in this artery there was but one fold, whereas he has represented several.

The inferior portion of the artery terminated in a cone, the apex of which was formed by the extremity of the artery closely contracted around a coagulum of lymph, which adhered intimately to its internal surface. Both extremities of the artery were surrounded with lymph, and the cellular membrane about them was filled with it to a considerable extent. See plate X. fig. 1 and 2.

EXPERIMENT XIII.

The femoral artery of a large dog was laid bare, and a tenaculum being then passed through the artery, rather more than one half of it was cut through. The other steps of the operation were after the manner of Experiment I.; but not one drop of blood followed. I visited the dog half an hour afterwards, but could not perceive any hemorrhage: he was lying very quiet. Two days after, taking him out of his kennel to perform another experiment on him, we found that the integuments around the wound were smeared with blood to the extent of about two inches in circumfer-

ence. Before he was removed from the table about two table spoonfuls of fresh blood had escaped from the wound; but there was no appearance of thrombus or distention of the integuments, and the discharge of blood had completely ceased; nor did I observe any return of hemorrhage from this wound.

Twenty-six days after the experiment the animal was killed, and on examining the limb on which it had been performed, the external wound was found to be completely healed, and there was no protuberance or tumor at the part. On dilating the integuments over the wounded part, the cellular membrane appeared filled with lymph, and was hard and gristly: this state of the cellular membrane was continued down to the artery, to which it adhered very firmly: on dissecting it off, the artery was found separated into two portions, the extremities of which were about one third of an inch distant from each other; each extremity terminated in a conical point: on cutting open both portions their canals were very much contracted to the extent of at least an inch from their extremities, each of which was filled up by a small coagulum of lymph, that adhered firmly all round to the internal surface of the artery.

It was this experiment which induced me to give up using a ligature for drawing out the arteries, and to substitute for it the aneurism needle. The ligature always appeared to alter the form of the artery more than the needle; and it is probable that in this instance in particular it had twisted the artery in the act of withdrawing it.

EXPERIMENT XIV.

I dissected down to the brachial artery of a large dog, and punctured it without removing it from its situation; the blood flowed very rapidly, and the wound was sewed up as quickly as possible: the animal lost a considerable quantity of blood, and appeared very faint before the hemorrhage ceased. The artery was punctured as high up as it could be conveniently got at.

Thirty days after the experiment the animal was killed, and the head and fore-legs injected from the aorta. On dissecting the axillary and brachial arteries of each extremity not the slightest difference could be perceived in them: the injection had passed uniformly through each, so that it was impossible, on examining them, to say which had been punctured. The cellular membrane, however, about that which had been wounded, was still somewhat thickened and hardened with lymph, and adhered more firmly about the artery; but it was by no means difficult to dissect it from the artery, and then there was no difference to be observed between it and the artery which had not been operated on.

EXPERIMENT XV.

I felt the left femoral artery of a dog pulsating very distinctly just under Poupart's ligament, and made an oblique puncture with a lancet sufficiently

deep to wound the artery; a very considerable discharge of florid blood immediately followed, a large thrombus was formed, and in about ten minutes the blood ceased to flow. Two days after, the tumor formed by the effused blood was very much diminished; and the integuments over the whole of the upper part of the limb, and under the abdomen, were much discoloured.

Eighteen days after the experiment, the limb having perfectly recovered its natural appearance, and no difference being perceptible between the pulsation of its artery and that of the right leg, I endeavoured to puncture the artery of the latter in the same manner as I had done the former. A very considerable hemorrhage ensued; but the colour of the blood did not appear quite so florid as in the former instance; the hemorrhage, however, was more profuse, and stopped in the usual manner.

The limb went through the same changes as the left had done, and as it was nearly in its natural state thirteen days after the experiment, I made an incision through the integuments and cellular membrane of that which had been first operated on, *i. e.* the left; and with a lancet made an oblique puncture through the fascia, and into the artery, which could be distinctly seen under the fascia; the integuments had been very much drawn aside previous to their being divided; so that by allowing them to slide over the artery as soon as it was punctured, and then sewing them up, they soon became very much distended with blood; and the external discharge of blood was moderate. The

day following, the parts appeared distended and tumefied.

Six days after, the limb appeared getting well so fast that I was induced to repeat the same experiment on the opposite hind leg, the right, attempting only to make the wound in the artery somewhat larger. The day following I found that the animal had pulled out the sutures from this last wound; the coagulated blood had escaped from it, and it had a smooth inflamed surface.

Six days after, the wound was very much contracted, but the adhesion of the integuments to the surface of the wound was by no means complete. The pulsation of the artery, through the whole extent to which it could be felt, appeared perfectly natural.

Eight days after the last experiment on this leg, I again punctured the left through the integuments, with the same effect as has been already described.

Thirty-six days after the first puncture had been made in the femoral artery of this dog, he was killed, and the posterior extremities were injected from the aorta.

On dissecting the femoral arteries and their branches of both legs, the injection was found to have passed without any interruption uniformly through both of them; no difference could be perceived between them, nor did either of them exhibit appearances differing from arteries which have never been operated on,

except that the cellular membrane surrounding them was thickened, and adhered in some parts with unusual firmness to the artery.

EXPERIMENT XVI.

I made an incision through the integuments and cellular membrane of the left hind leg of a dog, and punctured the femoral artery near Poupart's ligament through the fascia, which I had taken care not to wound previously. In this instance also the integuments had been drawn aside before they were divided, and by replacing them, and sewing them up, the hemorrhage, which was very rapid, was soon stopped, and the integuments were distended with blood.

Eight days after, finding that the wound appeared to be going through the same process as was described in the preceding experiment, I repeated this experiment on the right hind leg; and the same circumstances occurred as have been described on the left.

Five days after, the dog having allowed the sutures to remain in, the external wound was nearly healed; and a small hard substance was felt under the integuments, and which seemed to lie over the artery, as its pulsations were very sensibly felt by keeping the finger on it. The wound in the left leg being now completely healed, and the pulsation of the artery appearing every where natural, I punctured the femoral artery of this leg with a lancet passed obliquely through the integuments in the manner formerly described; a profuse hemorrhage of florid blood ensued; to check it I tied up the puncture in the in-

teguments, and they were soon very much distended with blood.

Two days after, the integuments on the upper part of the limb, and under the abdomen, were of a very dark colour, and, instead of the thrombus, a hard lump, not one sixth of its size, was now to be felt. The hard substance which lay over the artery of the right leg, in the course of a few days more, could no longer be perceived.

Thirty-nine days after the first experiment on the left hind leg of this dog he was killed, and both hind legs were injected from the aorta. On dissecting them no difference could be perceived between them; nor did either of them exhibit any deviation from their natural appearance: the injection had passed uniformly through them without obstruction at any point. The cellular membrane surrounding them was thickened, and adhered more firmly than natural.

SECTION II.

On the subject of the present, as well as the former chapter, we find ourselves under the highest obligations to the celebrated Mr. Petit for many, and, I believe, the first accurate observations. In his third Memoir* he gives the following account of the manner in which hemorrhage from a punctured artery is stopped. "Il est même un cas dans le quel le couver- "cle du caillot de l'artère ouverte est si solidement "placé, qu'il suffiroit seule pour arrêter l'hémor- "rhagie; c'est lorsque le sang s'est logé dans le tissu "cellulaire qui envellope l'artère; il est même ordi- "naire que cela arrive ainsi toutes les fois que l'artère "a été ouverte par un instrument piquant et tranchant, "tel qu'une lancette, parce que la lancette fait une "plus grande ouverture aux membranes de l'artere "qui ont quelque solidité, qu'elle n'en fait au tissu "cellulaire, qui n'en peut éviter la pointe, mais qui "peut eluder le tranchant par sa flexibilité, et par "son peu d'adhérence à la membrane externe de "l'artère. Or si l'ouverture de l'artère est plus grande "que celle du tissu cellulaire, il est claire que le sang "venant à sortir avec impetuosité, se logera dans ce "tissu cellulaire, et que se coagulant, il formera un "couvercle d'autant plus propre à retenir le bouchon

* See Memoirs of the Academy of Sciences for 1735.

" qu'il sera lui même retenu par les membranes de " toutes les cellules dans les quelles il s'est engagé: " c'est ce qui n'arrive point aux artères entièrement " coupées." This last sentence seems to have been introduced merely in consequence of Petit's having conceived the formation of " le couvercle" in the case of a *completely divided* artery to have been wholly independent of the cellular membrane; for he afterwards says in direct terms: " Que l'hemorrhagie de " l'artère simplement ouverte est arrêtée par un caillot " comme celle de l'artère entièrement coupée."

As far as regards the temporary means by which hemorrhage from punctured or partially divided arteries is stopped, I have but little to add to the account which I have just quoted from Mr. Petit; the accuracy of which my experiments seem to have confirmed. I shall therefore only observe, that the blood is effused into the cellular substance between the artery and its sheath for some distance both above and below the wounded part; and that when the parts are examined a short time after the hemorrhage has completely stopped, we find a stratum of coagulated blood between the artery and its sheath, extending from a few inches below the wounded part to two or three inches above it, and somewhat thicker or more prominent just over the wounded part than elsewhere; so that instead of saying that the hemorrhage is stopped by a coagulum, which perhaps, with respect to the arteries, always conveys to the mind the idea of a distinct form, it is more correct to say, that it is stopped by a thick lamina of coagulated blood, which, though somewhat thicker at the wounded part, is perfectly

continuous with the coagulated blood lying between the artery and its sheath. See Chap. II. Exp. I. and plate IV. fig. 1.

It would seem that when an artery is punctured, the hemorrhage which immediately follows, by filling the space between the artery and its sheath with blood, and consequently distending the sheath, alters the relative situation of the puncture in the sheath to that in the artery, so that they are not exactly opposite to each other; and by that means a layer of blood is confined by the sheath over the puncture in the artery, and by coagulating there prevents any further effusion of blood.

But this coagulated blood, like the external coagulum of a divided artery, affords only a temporary barrier to the hemorrhage; its permanent suppression is effected by a process of reparation or of obliteration which takes place in the wounded artery.

In considering these effects of a partially divided artery, it is of the utmost importance that we form clear and distinct conceptions of the nature and extent of the wound; for the slightest reflection on the elastic and contractile properties of the coats of arteries may convince us, that longitudinal, oblique, or transverse incisions will differ very materially as to the aperture which they will make in an artery, *i. e.* as to the distance to which they will occasion the lips of the wound to be separated from each other. The longitudinal appears to produce the slightest possible or perhaps scarcely any separation;* the oblique occasions

* See Note C.

a separation proportioned to its extent; and the transverse, however small, seems to produce a circular* aperture in the parietes of the artery.

It appears from my experiments that an artery, if wounded only to a moderate extent, is capable of re-uniting and of healing so completely that after a certain time the cicatrization cannot be discovered either on its internal or external surface;† and that even oblique and transverse wounds, when they do not open the artery to a greater extent than one fourth of its circumference, are also filled up and healed by an effusion of coagulating lymph from their inflamed lips, so as to occasion but little or no obstruction to the canal of the artery.‡ See Experiment II. and plate V. fig. 1 and 2.

It is difficult however to determine the precise extent to which an artery may be wounded, and re-united, so as to preserve the continuity of its canal; for it would appear, that when the wound is very large, though not completely beyond the possibility of being re-united, such a quantity of coagulating lymph is poured out, that the canal of the vessel at the wounded part is more or less filled up by it.§ And when the wound is still larger (suppose half of the circumference of the artery to be cut through), instead of the re-union of the coats or obstruction of the

* See Note D.

† See Experiments XIV. XV. XVI. of this chapter.

‡ See note E.

§ See Experiments IV. and VII. plate VII. and plate V. fig. 4.

canal,* the strong tendency to retract exerted by the divided parts, keeps the undivided portion constantly on the stretch, and it is either torn through after a short time as appears to have been the case in Experiment XII. plate IX. or else the irritation produced by its being kept constantly on the stretch, occasions a gradual ulceration of it, by which its complete division is accomplished. See Experiment XIII. plate X. fig. 2.

But I shall reserve for the chapter on secondary hemorrhage any observations which I may have to make on cases of this description, and shall confine myself at present to a detail of the progress of those cases, in which re-union or filling up of the wound of the artery is effected.

I have already observed, that longitudinal, oblique, and even transverse wounds of small dimensions, are filled up with coagulating lymph, effused from the inflamed edges of the wound in the artery; this lymph appears to be poured out very freely, not only from the artery, but also from the surrounding parts; and hence we find it accumulated around the artery, and particularly over the wound, at which part it forms a more distinct tumor.† Vide Experiment V. pl. VIII. fig. 1 and 2.

* Duæ igitur potissimè sunt causæ quibus vulneratæ arteriæ coire prohibentur; distantia nimirum ac distractio labiorum vulneris, ac motus sanguinis, alternaque arteriarum systole ac diastole: . . . . quamobrem aptari nequeunt ac glutine jungi ferruminarique. Lancisius de Aneurismatib. p. 15, prop. 11. Lauth Collect.

† See Note F.

But, at the same time, the surrounding parts which have been exposed become inflamed, and pour out lymph, so that the whole surface of the wound is covered by a layer of coagulated lymph, which completely excludes the artery from the external wound.* This lymph granulates, and the wound is filled up and healed in the usual manner.

Finally, from my experiments it appears, that it is extremely difficult to produce aneurisms in dogs and horses by wounding their arteries.

But since from the similarity of structure and functions of the parts in question in man and in these animals, we are authorized to conclude that they are similarly affected by the same causes, or that the same process, subjected, however, to many circumstances that interfere with its success, is attempted for the reparation of wounded arteries in man as we find accomplished in these animals, although the experiments have failed to produce aneurisms in dogs and horses; yet, by showing us what the process of reparation is in these animals, they may enable us to explain the manner in which aneurisms are formed in man. In fact, the formation of aneurism appears to be one of the most common effects of the failure of the process by which the artery would have been united. And from combining the pathological observations made on the human subject by writers on surgery, relating to the formation of aneurism, with the process of reparation

* See Experiments IV. and V. of this chapter; also plate VI. and fig. 1. of plate VIII.

in punctured arteries, as described above, I think it appears highly probable, that spurious aneurisms are formed, either in consequence of the lymph, which had been poured out for the re-union and filling up of the wound, being torn through by the impetus of the blood, soon after the wound of the integuments had healed; or else by the blood striking against, and gradually dilating into an aneurismal sac, the lymph which had reunited the artery.* We may be better prepared to conceive how the former effect may take place, by reflecting a little on the consequences of a wound in an artery of considerable size, which we know to be such a profuse hemorrhage as reduces the force of the circulation for some time; but this diminished force, together with the means usually employed, affords an opportunity for the natural process to go on; the effusion of lymph from and about the wounded artery takes place, and if the wound of the integuments is very small it reunites; but if the effused lymph has not had time to acquire a sufficient degree of firmness before the force of the circulation returns, or the unfortunate patient incautiously moves his limb, it is obvious that the lymph may be torn through, just as we know that newly cicatrized wounds (for instance, the wound after the operation for the hare-lip) are disunited by any force which the newly effused lymph is unable to bear.† It may also be that aneurism is formed in one or the other of these modes, according to the extent of the wound in the artery; thus, if the wound has been large, the surface of lymph against which the blood strikes is larger and more likely to be

* See note G. † See note H.

lacerated; but if small, it may escape laceration, but undergo gradual dilatation; and thus give rise to that very slow formation of aneurism which has been so repeatedly and universally observed.*

If these suggestions are allowed to be at all probable, it obviously follows, that it must be of the utmost importance to prevent and counteract as much as possible any violence of the circulation, particularly at the wounded part.† Hence the approach of fever must be watched and moderated by means suited to the constitution, &c. of the patient: the local impulse of the blood may, no doubt, be diminished by topical bleeding and by *posture*. The limb should be kept as completely at rest as possible, and such a degree of pressure made on the part as it will bear without producing tumefaction, or any other inconvenience;‡ and it will be necessary to continue that pressure for some time after the external wound has completely healed, when it may perhaps be admissible to increase the pressure a little.§ But let it not be understood that I mean to lay down this as the proper treatment of a wounded artery;‖ on the contrary, I am convinced, that in every case in which it can be done, it is best to tie the artery above and below the wounded part, and to divide it completely between the ligatures. This practice we find recommended even by Celsus, who says, "Quod si illa quoque profluvio

* Mr. J. Bell has related many cases which illustrate very strikingly this very slow formation of aneurism, although he has given a different account of their formation.

† See note I.

‡ See note J.

§ See note K.

‖ See note L.

" vincuntur, venæ, quæ sanguinem fundunt, appre-
" hendendæ, circaque id, quod ictum est, duobus
" locis deligandæ intercidendæque sunt, ut et in se
" ipsæ coeant, et nihilominus ora præclusa habeant."*

It is with great pleasnre that I find myself again enabled to bring forward the observations of Haller, in confirmation of those which my experiments have afforded me, and I trust, it is unnecessary to apologize for the length of a quotation from such high authority on so important a subject.

" Vulneravi arteriam; hæmorrhagia maxima spissi
" et coagulabilis sanguinis secuta. Venit is sanguis et
" à cordis sede, et ab eâ, quæ intestina proprior res-
" piciebat. Duo contrarii turbines ibant sibi obviam,
" et urgebant se per rimam vulneris. Extra arteriam
" globuli à se invicem utique divergent. Porro *nebula*
" *nata est rubri coloris*, eaque ipsa paulatim se dis-
" sipavit, *ut centrum rubore suo se distingueret, cum*
" *ambitus palidus esset.* Eodem tempore sanguinis ar-
" teriosi motus lentior fuit, et denique nullus ex vul-
" nere venit; qui vero in arteriis fuit, *is nativum iter*
" *recuperavit*, hac qua dicam ratione. Arteria in sede
" vulneris dilatata est, fere ad duplum diametrum
" prioris. Per eum tumorem modo unico, modo tribus
" quatuorve per albam nebulam serpentibus filis san-
" guis erepsit, et denique in verum fluentum, se per
" arteriam continuavit. Sed etiam in venis et hodie
" observavi et alias frequenter, duos tresve serpenti-

* Celsus de Re Med. lib. V. Cap. xxvi.

" nos torrentes per album, pellucidumque coagulum " sibi iter fecisse, et nativum sanguinis flumen restitu- " isse, neque tamen unquam *fere* eo in loco qui in- " cisus fuit plenum sanguinis rivum reparari, etiam " quando sanguinis motus in orbem restitus est. *Hu-* " *morem vero esse, qui arteriam vulnera replet, cer-* " *tum videtur, album, in gelatinæ speciem mutatum,* " *qui circa vulnus adhærescit.* Nam abraso arterioso " venosove vulnere, aut absterso, sanguis denuo ef- " fluit, ut ter in eâdem ranâ, inque eâdem ejus ani- " malis arteriâ id experimentum eodem modo evene- " rit."*

These very interesting observations not only confirm the account, which has been given, of the manner in which hemorrhage is stopped, and of the process of reparation which takes place in the artery, but also give us very curious information with regard to the manner, in which the restoration of the circulation through the artery is effected. As to his having scarcely ever observed the stream of blood to be fully restored at the wounded part, it must be remembered, that he never examined it any length of time after the experiment, but only immediately after having performed it. It appears extremely probable, that what Haller conceived to be a dilatation of the artery at its wounded part to almost twice its former diameter, was only an increase of size produced at that part in consequence of the effusion of blood between the artery and its sheath. That Haller did not pay a due degree of attention to the arterial sheath, appears from the follow-

* Haller, Op. Minor. Exp. 180, p. 103.

ing and many other passages in his Experiments: "Globuli ex vulnere arteriæ inter mesenterii membranas effusi celeriter *attrahuntur* ad parietes arteriarum ibique colliguntur. *Oportet* secundum vasorum parietes, cellulosam telam esse, ad quam et globuli sanguinis retinentur et bullæ aeriæ."*

May it not have been from inattention to this circumstance, that he was so much embarrassed to account for the motion of the blood, which had been effused from a wounded artery or vein, and which motion he at last referred to a particular attraction: this at least appears probable from many passages in his work, but particularly the following:

"Denuo motus fluiditatis *nescio quis*, ad pondus omnino non pertinens in globulis sanguineis adparuit. Solent secundum venæ incisæ parietes parelleli *per cellulosam telam invisibilem*, *tanquam per canalem*, venæ contiguum et parellelum, globuli decurrere ad utrumque venæ latus."†

I might quote many more of his experiments, in support of the account I have given of the manner in which hemorrhage is stopped, and of the effects produced on the artery. The same experiments also frequently describe the manner in which the circulation is restored in the punctured artery; but I shall content myself with referring only to a few of them.‡

* Haller, Op. Minora, Exp. 197. p. 115.

† Ibid. Exp. 215. p. 119.

‡ Ibid. Exp. 88. 170. 180. 185. 234.

I shall conclude this chapter with the following case from Petit, as a striking illustration that the same process of reparation takes place, and may be accomplished, in the human subject, as that which I have described from dogs and horses. Immediately after the very accurate observations, which, at the beginning of this section, I quoted from Petit, he gives the following interesting detail:

" Ce que j'avois cru pouvoir assurer fondé sur la " seule analogie, je l'ai demontré à l'academie le " Mercredi 3 Decembre, 1732; et le Samedi suivant, " j'y fis voir l'artère du bras d'un Homme qui étoit " mort subitement deux mois après avoir été par- " faitement guéri de l'ouverture de cette artère; je " montrai alors que les lèvres de la place de l'artère " n'étoient point réunies l'une à l'autre, mais que le " sang avoit été arrêté par un caillot *qui bouchoit* " *l'ouverture, et qui étoit adhérent à toute sa circon-* " *ference.*"*

Petit made experiments with this artery to ascertain of what the coagulum consisted; and he says, that after soaking it two months in water, which was changed two or three times every day, and three years in brandy, " J'ai montrai que le caillot n'avoit rien " perdu de sa consistance, ni de son adhérence à " l'ouverture de l'artère, d'où l'on peut conclure " que le caillot est une substance analogue à celle " des cicatrices; c'est ce que je voulois prouver."†

* Petit, Memoires de l'Acad. &c. de l'année 1735.
† Ibid.

From what has been already said of the manner in which wounds of arteries are healed, or filled up, it is unnecessary to comment on this case. It is sufficiently obvious, that an effusion of lymph had taken place from the edges of the wound in the artery, and hence the coagulum adhered by its circumference.

CHAPTER III.

ON THE OPERATION OF THE LIGATURE; SHOWING THAT ITS IMMEDIATE EFFECT IS TO DIVIDE THE MIDDLE AND INTERNAL COATS OF AN ARTERY, WHICH GIVES RISE TO THE ADHESIVE INFLAMMATION.

THE importance of investigating the immediate effect of a ligature upon an artery, and of ascertaining the best means of performing that operation, as well as the process which results from it, is too obvious to stand in need of illustration. In this chapter I propose to confine my observations to the first of these subjects, leaving the others for subsequent consideration.

From the changes which I observed in an artery after its complete or partial division, but particularly after a longitudinal wound of it, as well as its appearance after a ligature had been recently applied, I concluded that an artery is really cicatrized at its extremity in every case wherein the application of a ligature has the desired effect, *viz.* the prevention of hemorrhage. The same thing had been asserted by Petit and Morand in direct terms, but had not been proved. To make this manifest I was devising an experiment in which the internal coat of an artery might be wounded, when my worthy and truly intelligent

friend, Mr. J. Thomson, of Edinburgh, informed me that in every instance in which a ligature is applied around an artery, without including the surrounding parts, the internal coat of the artery is torn through by it. This gentleman, with his usual candour and liberality, added, that the fact had been first noticed by Monsieur Desault. Mr. Thomson, in the course of the following day, demonstrated to me on a portion of artery taken from the human subject, that the internal and middle coats are divided by the ligature. This was to my purpose, and gave rise to the following experiments, the results of which will not, I trust, be deemed uninteresting.

EXPERIMENT I.

August 6, 1803. A considerable portion of the right carotid artery of a dog was laid bare, and three ligatures were applied around it, close to each other, so as to cover nearly a quarter of inch of the artery. The ligatures were drawn tight enough to cut through the internal and middle coats of the artery, and then, by means of a piece of small twine, which had been laid along the artery, and on which the knots of the ligatures had been made, were carefully removed, so as not at all to injure the artery. Dr. Farre, who assisted me in this experiment, and myself then observed the artery, until we were convinced that the circulation through it was perfectly restored; and the only extraordinary appearance which we observed on the artery, was a slight impression made on its external surface by the ligatures. The external wound was then sewed up.

August 9th. The animal died this evening, in consequence of profuse secondary hemorrhage from one of his femoral arteries, on which an experiment had been performed.

Dissection. On cutting away the ligatures in the integuments covering the carotid, we found a quantity of thin pus in the wound, extending down to the artery, which however was covered and surrounded by a very thick layer of lymph, not only at the part on which the ligatures had been applied, but also about an inch below, and an inch and a half above. In proceeding to cut open the artery I only expected to find its internal and middle coat cicatrized, and its canal more or less completely pervious; but, to my great astonishment, it was completely obstructed and filled up with lymph, which not only adhered to, but appeared to form one substance with the parietes of the artery. The lymph at each of its extremities appeared rather of a dark red colour, in consequence of the adhesion of some red particles.

In consequence of my leaving Edinburgh soon after this experiment had been performed, I had no opportunity of repeating it for many months: at length, however, I obtained permission to perform it on a horse which had been sent to a slaughterer.

EXPERIMENT II.

January 24, 1804. The carotid artery of a horse was laid bare, and four ligatures were applied around

it, and then removed in the manner described in the first experiment. Dr. Farre assisted me in this experiment also, and we took care to be fully convinced that the circulation was complete through the artery before the external wound was sewed up.

January 27, the animal was killed. The ligatures with which the integuments had been sewed up still secured them; but from the depending situation of the parts, there was a considerable cavity between the integuments and muscles. There was a small quantity of pus over and behind the artery, which was surrounded by a very considerable effusion of lymph. See plate XI. On cutting open the artery at its extremity next the heart, we very soon came to a long coagulum of blood which filled up its canal, but did not adhere to its internal surface: at the extremity of this coagulum a projecting portion of lymph cohered and indented it: continuing to cut open the artery, the projecting lymph was only the extremity of a portion, which completely filled up its canal, for the space of about half an inch, and adhered so intimately to the internal surface of the artery, as to form but one substance with it: this lymph had on its surface four transverse lines, which seemed to mark where the ligatures had been applied. The other extremity of the lymph, or that next the head, also projected a little beyond the part at which it adhered to the internal surface of the artery: attached to this lymph we found a very long coagulum of blood, which appeared to fill up the canal of the artery, but did not adhere to its internal surface. See plate XI.

Having observed such extensive obstruction in the canal of the artery by the application of three ligatures in the dog, and of four in the horse, I wished next to ascertain what number of ligatures were sufficient to produce a complete obstruction, and therefore began by trying a single ligature.

EXPERIMENT III.

January 25th, 1804. A small portion of the carotid artery of a horse was laid bare, and tied with a single ligature. The ligature was then removed, as in the former experiment, and, the circulation being restored, the external wound was sewed up.

January the 28th, the animal was killed. There was a small cavity between the integuments and muscles, owing to the depending position of the parts, and no means having been used to keep them in contact. There was a little pus in the cavity, and a very little behind and about the artery, which was covered with coagulable lymph. The sides of the artery being minutely examined, to account for the formation of this pus, a loose portion of the ligature was found in the pus. The ligature had been made of several threads, and in cutting it away, one of these had been detached and left behind. This led me to examine the parts around the artery, on which the second experiment had been performed, and about which pus had also been found. I there discovered a similar loose portion of the ligature. To guard against this accident

in future, I determined to use a piece of firm small twine. On cutting open the artery, we found a septum of lymph standing across its canal, and firmly adhering to its internal surface. There was not however any coagulum of blood on either side of this septum of lymph, and therefore I conclude, that it must have had an aperture through which the blood passed: this aperture may perhaps have been rendered less distinct by the anterior portion of the septum having been injured in cutting through that part of the artery to which it adhered. The aperture is more distinct in the plate than in the preparation; but the greater thickness of the septum near the sides of the artery, than at the center of the canal, and the narrowing of the artery at that part, are very correct. See plate XII.

EXPERIMENT IV.

The result of the last experiment made me extremely anxious to repeat it. February 4, 1804, an opportunity offering, I proceeded to tie the carotid of a horse; but my ligature was bad; for, as soon as I attempted to draw it tight, it broke off close to the artery. I pulled, however, by the little remaining portion, as much as the very imperfect and slippery hold which I could take of it would allow, and then removed it very easily.

February 6th, the animal was killed. The artery being cut open, I found that it was completely pervious, and that the ligature had acted very imperfectly and partially on it: the internal and middle coats were not

at any part completely cut through. At one part, for the space of an eighth of an inch, they were cut about half as deep as they ought to have been; and to this part two slender coagula of blood adhered; but through the remaining circumference of the artery the mark of the ligature internally could only be traced by a slight, narrow, red line. It is obvious that the ligature, in consequence of its breaking in the very act of tying, had not produced those effects, on which the success of the experiment entirely depended: the failure of this experiment cannot therefore be considered as affecting the uniformity of the result of such experiments, when properly performed; and, on the other hand, illustrates a very interesting fact, which will be fully considered in the concluding chapter.

As I could not have many more opportunities of operating on horses, I determined in the next instance to use two ligatures.

EXPERIMENT V.

February 16th, 1804. A small portion of the carotid artery of a horse was laid bare, and two ligatures were applied around it, about one eighth of an inch from each other, in the manner, and with the view, described in Experiments I. and II. The ligatures were then cut away, and the integuments sewed up.

February 19th, the animal was killed. The canal of the artery was completely obstructed at the part on which the ligatures had been applied; and on cutting

it open, at some distance from the obstructed part, but between it and the heart, we found a considerable coagulum of blood in this portion of its canal, and which being removed, to ascertain the nature of the obstruction, it was discovered that this portion of artery terminated in the same manner as arteries do, on which a ligature has been applied and allowed to remain; i. e. in a conical impervious sac. The artery just beyond this point felt hard and solid, I therefore did not cut through its coat at this part, lest I should spoil the appearance I have just described; but proceeded to cut open the other portion of the artery between the head and the obstructed part, beginning at the extremity next the head. In this portion also we found a considerable coagulum of blood, which being removed, there appeared a small portion of lymph, of the form of a heart, projecting within the canal of the artery, the base situated next the coagulum of blood, the apex terminating in the obstructed part of the artery. Over the artery, and on each side of it, there was a considerable effusion of lymph, extending from rather more than an inch below the obstructed part to nearly an inch and an half above it. See plate XIII.

The integuments, from the cause before mentioned, were not adhering to the internal surface of the wound: that surface was formed by a very thick layer of lymph, which was lubricated with pus, but there was not the slightest accumulation of pus in the wound; nor was there any about the artery; nor was there any pus discovered in any of the experiments, except the second and third, in which the loose portions of ligature

were found: in the succeeding experiments I used small twine for a ligature, and was particularly careful to see that it was completely withdrawn.

The examinations of these experiments having been made only two or three days after they had been performed, although the appearances observed (as for instance, the considerable obliteration of the canal of the artery by lymph, which seemed to form but one substance with it, and the extensive coagula of blood which defended the lymph from the impulse of the circulating blood,) seemed to place, beyond doubt, an extensive obliteration of the artery; yet, as it might be more satisfactory to have direct experiments in proof of the permanency of the obliteration, I determined to make experiments with this view; but as I could not get horses kept long enough for this purpose, I was obliged once more to have recourse to dogs.

EXPERIMENT VI.

March 2, 1804. The right femoral artery of a dog was tied with two ligatures, in the manner and with the view formerly described; the ligatures were then withdrawn, and the integuments sewed up.

March 6th. The right brachial artery of the same dog was tied as high as possible in the axilla. The whole of the experiment was conducted as above described.

March 10th, the same experiment was performed on the left brachial artery.

In making the experiment on the right brachial artery, the internal parietes of the artery seemed to adhere so strongly to each other, that the circulation through the vessel was not restored for a minute or two after the ligatures were removed. In making an experiment of this sort, the restoration of the circulation through the vessel should always be obtained. Although, in a practical point of view, it may be an advantage for the internal parietes to cohere, and thus their wounded surfaces may escape that impediment to their adhesion, which a stream of blood passing between them must occasion in a greater or less degree.

March 18th, the animal was killed. On examining the arteries on which the experiments had been performed, their canals were found to be completely obstructed with lymph, which adhered so firmly to the internal surface of the artery as to form but one substance with it. On each side of the obstruction there were coagula of blood in the canal of the artery. Over its external surface, and in the parts immediately surrounding it, there was a considerable effusion of lymph. The wounds in the integuments of the two former experiments were completely healed, and that in the latter experiment was very nearly closed.

From the changes which we know that arteries begin to undergo very soon after a complete obstruction has been made to the passage of the blood through them,

there can be little reason to doubt the efficiency of the obstruction, produced in the manner described in these experiments, to occasion a complete obliteration of the artery to the first collateral branches above and below the obstructed part. The changes here alluded to I shall consider in the next chapter.

In the preceding parts of this treatise, I have uniformly endeavoured, without distorting or straining any fact whatever, to show from some of our best writers on surgery, that the same effects are produced on the arteries of the human subject, as on those of dogs and horses, by the same causes: how far this similarity of effect has been satisfactorily proved, each individual must determine for himself: to me it appears sufficiently established to afford a reasonable expectation, that the obstruction produced in the arteries of dogs and horses, in the manner above described, might be effected, by the same treatment, in the arteries of the human subject; and if it should prove successful, it might be employed in some of the most important cases in surgery. The success of the late important improvements which have been introduced in the operation for aneurism, may perhaps appear to most surgeons to have rendered that operation sufficiently simple and safe; but if it be possible to produce obstruction in the canal of an artery of the human subject, in the above-mentioned manner, may it not be advantageously employed in the cure of aneurism? inasmuch as nothing need be done to prevent the immediate union of the external wound. The operation may then be considered merely as a simple incised wound. It is scarcely necessary to observe, that I

allude to the operation itself; of course if this operation can be adopted, it must be subject to the same previous considerations, with regard to the diseased state of the artery itself, or of the arterial system, &c. which precede every other mode of operating. May not this mode of obstructing the passage of blood through arteries be also used with advantage in cases of bronchocele? There may be other cases in surgery in which it may prove useful, but I shall not dwell longer on what may appear to be premature suggestions and queries.—I leave the fact for those who have opportunities of applying it in practice, when all the circumstances which determine its success or failure shall have been fully ascertained by further experiments on brutes: it is enough for my present purpose to have pointed out the true principle on which the ligature acts.

CHAPTER IV.

ON THE PROCESS OF ADHESION, AND THE CHANGES WHICH AN ARTERY FINALLY UNDERGOES, IN CONSEQUENCE OF THE APPLICATION OF THE LIGATURE.

SECTION I.

THE subject of the ligature has been treated by some of the most eminent writers on surgery, and most of the facts with regard to it are well understood; but in a subject of such great importance, it is necessary that all the changes, and the order in which they happen, should be ascertained.

In relating the experiments undertaken with this view, I shall first give an account of those in which a ligature was applied on the cut extremity of the artery, or in which two ligatures were applied on the vessel, and the intermediate portion completely divided; and secondly, of those in which the artery

was tied with one or two ligatures without being divided.*

It is also to be observed, that the ligature was always made on the artery alone, without including its sheath or any of the surrounding parts.—The authority of many of the best writers on surgery,† and of several eminent surgeons of the present day, together with the view which my first experiments had given me of the effects of a ligature, so sufficiently convinced me of the superiority of this mode of practice over the other, that it appeared to me unnecessary to put an animal to the additional pain which including surrounding parts, and consequently nerves in the ligature, would certainly have occasioned.

EXPERIMENT I.

I laid bare the carotid artery of a dog, included nearly an inch of it between two ligatures, divided the artery between the ligatures, and sewed up the external wound. The cut extremities of the artery retracted about one third of an inch.

* This order will be preserved, except in Experiment XIII. in which the artery was divided, but the time at which the examination took place requires that it should be arranged in the second division.

† To the late celebrated Dr. Monro, of Edinburgh, in particular, we are indebted for many truly judicious and valuable observations on this subject.

Six hours after the experiment the animal was killed. The edges of the integuments already adhered to each other at two points by means of lymph. The cellular membrane between the integuments and muscles was of a red colour, had a smooth feel, and polished appearance; and numerous vessels were seen running over its surface. One part of the wound was discoloured with blood; but the inflamed vessels of the cellular membrane chiefly gave it a red appearance. A considerable layer of coagulable lymph extended from just below the ligature on the inferior portion of the carotid, to above the ligature on the superior portion, thus completely covering both extremities of the artery, and the space between them. It also adhered firmly to the muscles on each side of the artery. On tearing a portion of this lymph, its fibrous texture was already very apparent; and numerous small red points were observed on its surface.

Both portions of artery were opened, but no internal coagulum of blood was found: each contained a little fluid blood, but not more than is commonly met with in the arteries immediately after death. Each extremity of the artery was thickened, and when cut, seemed softer near the ligature then elsewhere.

EXPERIMENT II.

The humeral artery of a dog was tied in two places, and divided between the ligatures. It retracted as usual. The integuments were brought together by two sutures.

Twenty-four hours after the experiment, the dog was killed. The wound seemed to be almost united, but admitted of being forced asunder, and then discovered a considerable quantity of effused lymph, of a reddish colour, and somewhat granulated appearance. Pus was forming in the course of the ligatures, which were yet firm on the artery. The internal and middle coats of the artery, which had been cut through and brought into contact by the ligatures, cohered. It was not yet perceptible, that ulceration had taken place at the extremities of the artery, where they had received the impression of the ligatures. From the upper portion of the artery the circulation was continued by several collateral branches, which prevented the formation of an internal coagulum of blood.

In the lower portion there was a very inconsiderable coagulum of blood, which slightly adhered to the closed extremity of the artery.

EXPERIMENT III.

The femoral artery of a dog was divided between two ligatures, and each portion instantly retracted within the arterial sheath, as far as the ligatures would admit, leaving a space of one third of an inch. The integuments were closed by a single suture.

Forty-eight hours after the experiment the dog was killed. The wound, which was nearly united, being forced asunder, the cellular membrane was found to be much thickened with lymph. The internal surface of the

wound appeared to be very vascular, the lymph having a red and granulated appearance. A small abscess pointed out the situation of the ligatures, which had occasioned ulceration of the external coat of the artery to such an extent, that they came away on using a very slight force. Both portions of the artery being cut open, it was ascertained, that each was uniting at the wounded part into a pouch-like extremity. In the upper portion there was no internal coagulum, in consequence of the ligature having been applied just below a collateral branch; nor was the lymph that united the extremity of this portion of the artery in sufficient quantity to be perceptible.

In the inferior portion of the artery there was a small coagulum of blood, which was loose towards the canal of the artery, but adhered to the pouch-like extremity by lymph, which was more apparent in it than in the upper.

EXPERIMENT IV.

See Chap. I. Experiment XVIII. and plate III. fig. 1. for the representation of the state of an artery seventy-two hours after a ligature had been applied on it. The detail of that part of the experiment which relates to the effects of the ligature I shall now subjoin.

A piece of coarse twine was laid along the portion of the carotid next the heart, and included with it in a ligature, about half an inch from the ligature at the

extremity of the artery, so as to keep the blood contained between the two ligatures perfectly at rest. This was done to ascertain, if, in a given time, the formation of a firm coagulum would take place at the extremity of the artery, fill up its canal, and form a substantial obstruction to secondary hemorrhage.

Four hours after, by means of the piece of twine which had been included with the artery, I withdrew the ligature which had been applied half an inch from the extremity of the artery. This ligature had been tied with one knot, and that only tight enough to confine the blood. It was therefore readily withdrawn, and without occasioning any disturbance to the other parts.

Seventy-two hours after the operation, on cutting open the artery, a coagulum of blood appeared nearly half an inch long; but, being examined more attentively to discover if it adhered to the sides of the vessel, I found that it was in reality rather more than an inch long; that a portion of it filled the canal of the artery for at least a quarter of an inch, but that the remainder was of a tapering form, and had been doubled up and compressed by the injection that had been thrown into the artery. This coagulum did not adhere to the internal surface of the vessel; but was slightly attached to the newly cicatrized part just under the ligature, which still remained on the artery.

EXPERIMENT V.

The carotid artery of a dog being exposed, a ligature was applied on it, and the artery divided about three lines' breadth from the ligature, between it and the head of the animal. The external wound was closed with sutures.

Four days after, the dog was killed. On examining the wound, the integuments were found open, the animal having got out the sutures; in consequence of which the wound, although much contracted, had a deep appearance. On dilating the integuments, we found that the surface of the wound was formed by a thick layer of coagulable lymph, which appeared very vascular, and was thinly covered with pus.

This layer of lymph being cut through, and the artery, which adhered to it very firmly, exposed, we found it much thickened, to the extent of at least one third of an inch from its extremity. The ligature was still on, but had occasioned ulceration and separation of at least two thirds of the circumference of the artery. A black conical coagulum, about a quarter of an inch long, was found within the extremity of its canal, which it did not completely fill; nor did it adhere to the side of the artery; but was slightly attached to the part which had been recently united by the application of the ligature, and which appeared to be a mere point, the extremity of the artery being so contracted as to form a cone.

EXPERIMENT VI.

The femoral artery of a young dog was laid bare; two ligatures were applied around it, about three quarters of an inch from each other, and the intermediate portion was completely divided. The cut extremities immediately retracted nearly half an inch from each other. The external wound was sewed up.

This dog died six days after, in consequence of very extensive intus-susceptio and inflammation of his intestines. On examining the limb, the external wound was found to be very much contracted, but not completely healed. Its surface had the same appearance after the integuments were dilated, as has been described in the last experiment. The artery being exposed, it appeared, that the posterior part of the layer of lymph that formed the surface of the wound, was firmly attached to the inferior portion of the artery, a little below the ligature, and extended up to the superior extremity of the artery, which it also covered and adhered to firmly. The ligature, which had been applied on the superior portion of the artery, had escaped, and could not be found; the extremity of the artery was completely closed and covered with lymph. Being cut open, its tunics appeared very much thickened, and a small black coagulum, that was not attached to any part, was found at the end of its canal, which was very much contracted. On the inferior portion of the artery the ligature still remained; its tunics were very much thickened, and surrounded with lymph,

and a very small black coagulum was found at the extremity of its canal, which was completely united, and very much contracted. Withdrawing the coagulum, to examine the termination of the canal, it did not adhere to any part, but was confined by the contraction which the artery had undergone.

EXPERIMENT VII.

Two ligatures were applied around the carotid artery of a dog about an inch from each other; the ligature nearest the heart was tied very tight, that next the head was tied in the usual manner; the artery was not divided between the ligatures, and the external wound was sewed up.

Eleven days after the experiment, the animal was killed; the external wound was very much contracted, but not healed. Its surface was covered with pus, that seemed to issue from under the sterno-mastoid muscle, which being raised, we found a cavity between it and the artery, containing a small quantity of pus, and a sinus extending from the cavity about an inch and a quarter by the side of the artery towards the heart. The ligatures were not to be found, but they had probably occasioned the formation of this abscess; and the erect position of the head had favoured the extension of the pus by the side of the artery. The artery was separated into two distinct portions, about an inch distant from each other; but the extremity of the portion next the heart was so completely enveloped in lymph, which adhered to it too intimately

to be dissected off, that it was impossible to say exactly where it terminated: this lymph gave the extremity of the artery the appearance of being much larger than any other part of the vessel; which indeed had contracted so much, that it was very much smaller than the corresponding portion of the other carotid. The coats of this contracted portion of the carotid appeared remarkably thick and white, except about half an inch of it next the extremity, which was of a very dark colour, occasioned by a coagulum of blood that did not adhere to the internal surface of the vessel, but had rendered it very black, probably in consequence of the artery being firmly contracted round the coagulum, and of the absorption of the latter having commenced.

The extremity of the superior portion of the artery was completely closed, and of a conical form; it was covered with lymph, the cellular membrane surrounding it was thickened and indurated, and there was a small coagulum of blood within its canal.

EXPERIMENT VIII.

A small portion of the carotid artery of a large dog was laid bare, and a single ligature applied around it in the usual manner. The external wound was then sewed up.

Twelve days after, the animal was killed; and on examining his neck, I found the wound, in appearance, filled up and healed, except for the space of about a

six-pence, which was covered with pus; but on wiping away this matter, and making gentle pressure around the part, it was immediately covered again with pus. A probe was passed, and there appeared to be a deep sinus, which being dilated was found to extend to the part of the artery that had been tied, and to which the ligature was still attached. After a free dilatation of the parts, we found that the artery was covered, to a considerable extent above and below the part which had been tied, with a thick layer of coagulable lymph, through which the ligature was projecting. The posterior and lateral parts of the artery resembled a small ligament, for the space of one third of an inch, at the part which had been tied; and each portion of it was of a conical form. Both contained coagula of blood, which had the exact form of the artery, but did not adhere to its internal surface, as far as they could be examined without turning them out of its canal: they were obviously confined by the artery at their extremities next the obliterated part; for at each extremity was distinctly seen, what was originally the base of the coagulum converted into the apex by the contraction of the artery.* The ligature must have been detained merely by a few fibres, as I could not detect it, either at the posterior or lateral part, although I cut into them as much as I could without destroying the small, obliterated, ligamentous portion of the artery. See plate XIV. fig. 1.

* See Note M.

Although I attended closely to this animal from the time of the experiment until his death, I never once observed any hemorrhage from the part.

EXPERIMENT IX.

The carotid artery of a dog was tied with two ligatures, which were applied about an inch from each other, but the intermediate portion was not divided. The external wound was sewed up.

Nineteen days after, the animal was killed. The external wound was completely healed. The cellular membrane was very much thickened and indurated down to the artery, to which it adhered very firmly. The artery had been previously injected, and on cutting it open from the aorta upwards, we found its canal very much diminished, and more and more so, as we approached the part which had been tied. At the termination of the injection, which was nearly two inches from the aorta, there was a black coagulum that did not adhere to the internal surface of the artery, but terminated in a point at its contracted extremity, which was very thickly surrounded with lymph, involving also the nerve, and giving the extremity of the artery a bulbous appearance. From this extremity a thick layer or column of lymph extended to the extremity of the upper portion of the artery.

The extremity of the upper portion of the artery was so thickly covered with lymph, that it was ex-

tremely difficult to get a distinct view of it. On cutting it open, from under the inferior maxillary bone towards its extremity, we found its canal very much contracted, to the extent of at least two inches from the extremity. The injection had insinuated itself into this part, but was extremely slender and tapering. It will be remembered, that this portion of the artery was supplied with blood only by anastomosing branches, and consequently there was no impetus of the blood to resist its gradual contraction and obliteration. From the termination of the injection to the extremity of the artery, a space of about one third of an inch, its canal was completely obliterated, and its coats were converted into a firm, thick, solid substance. No discharge of blood had ever been observed from this artery after the experiment.

EXPERIMENT X.

The humeral artery of a dog was tied, as high as it could be reached, with a single ligature; and the external wound was sewed up.

Thirty-three days after the experiment, the animal was killed. Not the slightest discharge of blood had ever been observed. The external wound was completely healed. On cutting open the integuments, and dissecting down to the artery, the cellular membrane appeared slightly thickened. The artery was completely obliterated, from just below a collateral branch in the axilla, to the extent of at least an inch and a half

down the humerus; through the whole of which space the artery was not larger than a nervous filament: below this portion, where the artery again became pervious, it was very much contracted; showing that a more extensive obliteration of it was going on.

EXPERIMENT XI.

The right femoral artery of a large dog was tied with a single ligature. The corresponding part of the femoral vein was also tied, at the same time, with a separate ligature; and the external wound was sewed up.

Thirty-seven days after, the animal was killed. No hemorrhage had ever been observed from the wound, which was now completely healed. The posterior extremities were injected from the aorta. The artery, on which this experiment had been performed, being dissected, we found it completely obliterated and converted into a slender ligamentous band, for the space of an inch and an half, at the part which had been tied: At each extremity of this obliterated portion, a considerable lateral branch was given off, each of which anastomosed freely with the other. The trunk of the artery below the obliterated part appeared fully proportioned to that above it; the injection had passed very freely into it by the anastomosing vessels, and even the vessels going to the toes were completely filled. The muscles of the leg had a perfectly natural, deep red appearance, and the injected branches of the

artery were seen ramifying freely through them; but the muscles of the thigh were most minutely injected: the vastus externus, in particular, had a most beautiful appearance; by merely dissecting off its fascia, numerous small branches might be seen anastomosing through it: it is principally supplied with blood by the profunda, and a considerable branch above the knee. A very large anastomosis was traced between the profunda and another branch arising just above the knee. The artery just before it passed on the back part of the knee joint, gave off a considerable branch, which formed several anastomoses with the ischiatic artery on the inner side of the glutæus maximus. Another branch from the inferior portion of the femoral artery, given off higher up above the knee, anastomosed very freely, in one of the posterior muscles of the thigh, with a branch from the ischiatic: almost every one of these anastomosing branches had a very serpentine course; the artery was much convoluted, and most of the anastomoses formed small circles; thus, when two branches, one from above, and the other from below, approached each other, at some little distance before they met, each divided into two smaller branches, which anastomosing with each other, formed a small circle or oval. A considerable branch was sent off from one of the lumbar arteries, and passed close under the integuments, and over the fascia of the thigh, giving off many branches to the integuments in its course, and terminating in repeated anastomoses with the arteries about the knee.

The vein was obliterated to a greater extent than the artery, and the superior and inferior portions com-

municated freely by branches which passed from one to the other.

EXPERIMENT XII.

The left femoral artery of the dog that was the subject of the last experiment, was tied with a single ligature, and the external wound was sewed up. It is to be observed, that this experiment was performed before that which has been just detailed; but as the examination of it took place at a more distant period after the experiment than the former, it is here related after it: my motive for operating on both hind legs of the animal was to ascertain if the effects of tying up the vein as well as the artery differed from those which were produced by tying the artery alone.

Forty-nine days after this experiment, the animal was killed. There had never been any discharge of blood from the wound, which had been for many days completely healed. It was stated in the preceding experiment that the extremities were injected from the aorta. On cutting open the integuments over the artery, we found a small circumscribed abscess in the cellular membrane, between the integuments and the fascia; this abscess contained a small quantity of pus, and the ligature with which the artery had been tied.

On dissecting down to the artery, we found it obliterated, to the extent of at least an inch and a quarter, at the part which had been tied: at each

extremity of this obliterated portion, lateral branches were given off; *viz.* on the inner side of the femoral artery, the anterior tibial, immediately below the obliterated portion; on the outer side of it, two branches of moderate size, one just above, and the other immediately below the obliterated part: although the lower branch was given off at rather an acute angle, its ramifications stretched out laterally, and anastomosed freely with the small branches of that which was given off above the obliterated part; one branch, in particular, dipped deep into the muscle, and then turned directly upwards, and united with the superior branch. Two branches from the inner side of the femoral artery, given off one a little above, and the other below the obliterated part, soon divided into five smaller branches, which anastomosed with each other. From the upper part of the femoral artery, a considerable branch passed down, immediately under the rectus cruris, and anastomosed freely with several small twigs above the knee. The anastomoses were formed precisely in the manner described in the last experiment, *i. e.* by tortuous branches, most of which anastomosed in small circles or ovals. The other principal anastomoses, formed by the profunda and ischiatic with branches from the inferior portion of the femoral, just above the knee, were precisely similar to those described in the preceding experiment. The principal anastomoses however appeared somewhat larger; but the muscles of the thigh, although very vascular, by no means exhibited so many vessels as those of the opposite limb. Did this depend on the obstruction which had been made to the return of the blood in the right leg by tying up the vein, in consequence

of which a greater number of small arterial ramifications had been increased in size, so as to become visible? or did it depend on the different periods at which the examinations of the limbs took place, and had the muscles of the left leg lost a certain degree of their apparent vascularity in consequence of the contraction of the numerous small vessels which had at one time been visible? It has been observed that the principal anastomoses of the left leg were somewhat larger than those of the right: it is probable that as those principal anastomoses increase in size, many of the smallest visible branches contract and disappear.

These questions are perhaps of little consequence as to experiments of this kind; for whatever difference may have been observed in the vascularity of the muscles of these limbs, or in the size of their anastomoses, the injection had passed as freely through every part of each limb, and even the arteries going to the toes of each, were as completely filled, as if there had been no obstruction whatever in any part of the artery.

EXPERIMENT XIII.

I laid bare a very small portion of the left carotid artery of a dog, applied two ligatures on it, about one third of an inch from each other, and divided the artery between them: the divided extremities retracted very little from each other, less than I had observed in any former instance; probably in consequence of the artery having been so little detached

from the surrounding parts. The external wound was then sewed up.

Forty-nine days after the experiment, the animal was killed; and the carotids were injected from the aorta. The external wound was completely healed; and on dissecting the left carotid from the aorta upwards, it was found, that the injection had not passed more than an inch up its canal, which was very much contracted, so that this portion of the artery was considerably smaller than the corresponding portion of the right carotid. From the point at which the injection terminated, the artery was much more contracted; felt like a hard cord; and was of a dark gray colour, for the space of about an inch and a quarter. It was cut open with some difficulty, as its canal was completely closed; its tunics were found remarkably thick, *and its internal surface of a black colour, but there was no coagulum within it.* The artery terminated in a firm, white, conical portion, about a quarter of an inch in length, and which was united to the extremity of the superior portion by a small ligamentous band of lymph, about one third of an inch long.

The extremity of the portion of the artery next the head had also undergone complete consolidation, and was very similar to the other extremity. Its canal was completely obliterated for the space of an inch and a half from its extremity; and through the whole of this extent, it was very much diminished in size, and had a ligamentous appearance: from the end of this obliterated part to the first lateral branch, its canal was

very much contracted, and was of a conical figure, the apex being next the obliterated part, showing that it was also undergoing obliteration: the injection however had passed into this contracted portion below the lateral branch.

This superior portion of the carotid anastomosed very freely with the right carotid, both before and behind the trachea, and also with the left vertebral by a very large branch. The left vertebral and the right carotid were very much increased in size. From the posterior part of the curvature of the aorta, just between the carotids, a very considerable branch was given off, and passed up between the trachea and œsophagus, for some distance on the right side, and then turned off obliquely to the left side of the œsophagus, and formed a considerable anastomosis with a ramification of the lateral branch, given off from the superior portion of the artery. See plate XV.

EXPERIMENT XIV.

The left femoral artery of a young dog was laid bare, and tied with two ligatures, about half an inch distant from each other: the intermediate portion was not divided. The external wound was sewed up.

Six days after the experiment I observed, that almost the whole of the inner surface of the limb was wet with serum tinged with blood. There was also a discharge of pus from the wound. The day following, the integuments around the wound were covered

with a purulent discharge very deeply tinged with blood. Ten days after the experiment, the wound was almost healed.

Eighty-one days after the experiment, the animal was killed, and the hind legs were injected from the aorta. On dissecting them, we found, that the left femoral artery was obliterated, to the extent of an inch and a quarter, at the part which had been tied: this obliterated portion was so extremely slender, that it was difficult to preserve it; and at each extremity of it, there was a lateral branch, which anastomosed very freely with the other. It would be tedious to describe the numerous anastomoses, observed in the various branches of this limb; they were much larger than those described in Experiments XI. and XII. although this animal was much smaller than that on which those Experiments had been performed; but like them, they were chiefly formed in circles, and the branches, by which they were formed, were extremely tortuous, which rendered them very beautiful, particularly when they were first exposed, as the loose state of the muscles, and the necessary distortion of them, to get at the arteries, for the purpose of dissecting them, very much diminished their tortuous appearance. The muscles of this limb were florid and healthy, but they did not exhibit that minute and extremely vascular appearance, which was observed in the experiments referred to above. The principal anastomoses were formed by the same branches as in those experiments, *i. e.* by the profunda and ischiatic, above the obliterated part, and by branches from the inferior portion of the femoral, particularly about the knee,

below. In this animal also these was a considerable branch from one of the lumbar arteries, which passed close under the integuments, down the thigh, and anastomosed with branches about the knee. On comparing the arteries of this limb with those of the right, the trunks of the branches, by which the anastomoses were formed, were evidently larger than the corresponding trunks of the right leg; but the principal difference was observed in the extreme and inosculating branches; for in the left leg, the inosculations or anastomoses were extremely numerous, large, and formed by tortuous branches, uniting so as to form small circles or ovals; whereas, in the right leg, very few anastomoses could be traced, although the smallest branches were followed, even into the muscles, with the utmost minuteness. The few anastomoses which were found were extremely small, and formed by branches passing in a direct line with each other, not in the least tortuous. This difference cannot be imputed to the manner of injecting, because both extremities were filled by a single injection from the aorta just above its bifurcation.

SECTION II.

The first effects of the ligature upon an artery are, a complete division of its internal and middle coats, an apposition of its wounded surfaces, and an obstruction to the circulation of the blood through its canal. The artery does not become unusually distended in consequence of this obstruction;* principally because the collateral branches afford a passage to the blood, and partly in consequence of the effect which the obstruction to the arterial canal, and the pressure made by the ligature, have in depriving that portion of the artery of the property of accommodating itself to the quantity of blood determined to it: a property which it has frequently been observed arteries are endued with, to a certain extent, when entire and free from pressure,† and which is beautifully illustrated by the almost immediate enlargement which the collateral branches have been observed to undergo, when a trunk has been tied.‡ From these circumstances it appears, that the enlargement of the portion of the artery, between the first collateral branch and its extremity is prevented; but it is obvious that there must be a small quantity of blood just within the extremity of the artery, and which is more or less completely at rest; it therefore coagulates, but does not appear in

* See Note N.

† See Note O.

‡ See Note P.

every instance to form at once a coagulum, capable of filling up the canal of the artery; for, as may be observed in many of the experiments, several hours after the artery had been tied, there was only a slender coagulum formed in its extremity. I am therefore disposed to think, that although the artery cannot accommodate itself to the blood determined to it, yet it undergoes such a degree of contraction, as occasions too much motion in the blood which it contains, to admit at once of its complete coagulation.* It is a fact, that in most cases only a slender coagulum is formed at first, which gradually becomes larger by successive coagulations of the blood; and for the same reason it is, that the coagulum is always at first of a tapering form with its base at the extremity of the artery. But the formation of this coagulum is of little consequence; for soon after the application of the ligature, the extremity of the artery begins to inflame; and the wounded internal surface of its canal, being kept in close contact by the ligature, adheres and converts this portion of the artery into an impervious, and at first slightly conical sac.† It seems to be entirely owing to the effusion of lymph, by which this adhesion is effected, that the coagulum of blood, formed within the artery, is sometimes found adhering by a small part of its *base* to the extremity of the artery. But whilst the adhesion of the internal parietes of the artery is accomplished, a considerable quantity of lymph is effused between its coats, and among the parts surrounding its extremity;

* See that sentence in note N which begins "Sensim vero," &c.

† See plate XIV. fig. 2.

so that, in a very short time, the extremity of the artery is enveloped in lymph, and covered with a layer of it, just as we have seen the punctured artery to be.* After a short time, the ligature occasions ulceration of the part around which it is immediately applied; and, acting as a tent, a small aperture is formed in the layer of lymph effused over the artery; through this aperture a small quantity of pus is discharged, as long as the ligature remains; and finally, the ligature itself also escapes, and the little cavity, which it has occasioned, granulates and fills up, and the external wound heals in the usual manner; leaving a considerable thickening and induration of the cellular membrane, extending a little beyond the extremity of the artery. See plate XIV. fig. 2.

But since a certain degree of ulceration and formation of pus appear to be the necessary effect of the ligature, and this ulceration takes place as near as possible to a newly cicatrized part, and as it is a well known fact, that such parts very readily ulcerate, it is obvious, that every possible means should be employed, to prevent the extension of this ulcerative process: hence we should guard against the accumulation of pus about the extremity of the artery, by such pressure as the parts may conveniently bear; by placing the limb in such a position as will allow a ready exit to the pus; and, in some instances, by the application of sponge.

* See plate XIV. fig. 1.

It is certainly desirable, that the ligature should come away as soon as possible, yet I am convinced, that great care is necessary in endeavouring to expedite this event. We should always remember that so long as the attachment of the ligature appears to have any degree of firmness, any force exerted on it (as for instance, by pulling it rather strongly,) must act more or less on the recently cicatrized extremity of the artery, which is not only contiguous to it, but is still in union with that portion of the artery which detains the ligature; for it is the external coat of the artery, which hinders the separation of the ligature, partly, in consequence of its undergoing ulceration slowly, and partly, because the ulceration, which takes place in the first portion of the artery, by rendering the ligature loose, diminishes very much its power of promoting ulceration through the rest of the artery. But so long as any portion of this external coat remains entire, it is continuous with the external coat of the newly cicatrized portion of the artery, and therefore any force exerted on the former may be extended to the latter: hence it appears most prudent, that so long as our attempts to draw away the ligature meet with much resistance, they should only be exerted in such a gentle and gradual manner, as may promote ulceration of the part by which the ligature is confined, without endangering laceration of the recently united parts.

The permanent changes which take place in an artery, and in the circulation through a limb, in consequence of the application of the ligature, are precisely the same as those which happen from the

division of an artery, and which I have described in Chapter I. Section III. The portion of the arterial trunk which has been tied, undergoes a gradual contraction and obliteration to the first collateral branches, and finally dwindles to a mere fibre.*

The collateral branches are usually distended and excited to stronger action from the moment that a complete obstruction is formed in the trunk, and consequently, the commencement of their enlargement may be referred to that period.† Their increase of size seems to be proportioned to the exigencies of the particular case; thus, if the limb has been amputated, it does not appear to be finally very considerable, but if the limb remain entire, and only the natural course of the circulation be obstructed through the main arterial trunk, their enlargement is much more conspicuous,‡ and is particularly observable in the small inosculating ramifications of the collateral branches, by which the circulation appears to be carried on, after a certain time, as vigorously in the limb, the principal artery of which has been obstructed, as in that, which has preserved its natural circulation.§ See experiments XI. XII. and XIV.

The effects of tying an artery properly appear then to be the following:

1°. To cut through the internal and middle coats of the artery; and to bring the wounded surfaces into perfect apposition.

* See Note Q. Also Experiments X. XI. and XIII. of Section I. of this Chapter.

† See Note P. ‡ See Note R. § See Note S.

2°. To occasion a determination of blood on the collateral branches.

3°. To allow of the formation of a coagulum of blood just within the artery, provided a collateral branch is not very near the ligature.

4°. To excite inflammation on the internal and middle coats of the artery by having cut them through, and consequently, to give rise to an effusion of lymph, by which the wounded surfaces are united, and the canal is rendered impervious: to produce a simultaneous inflammation on the corresponding external surface of the artery, by which it becomes very much thickened with effused lymph; and at the same time from the exposure and inevitable wounding of the surrounding parts, to occasion inflammation in them, and an effusion of lymph, which covers the artery, and forms the surface of the wound.

5°. To produce ulceration in the part of the artery around which the ligature is immediately applied, *viz.* its external coat.

6°. To produce indirectly a complete obliteration, not only of the canal of the artery, but even of the artery itself to the collateral branches on both sides of the part which has been tied.

7°. To give rise to an enlargement of the collateral branches.

In the account which I have now given of the effects of the ligature on an artery, I have had in view

only those instances, in which the ligature has been applied on the extremity of a divided artery, or those in which two ligatures have been applied on an artery, at a small distance from each other, and the intermediate portion divided. But, from observation on the human subject, it appears, that the effects are different, or at least their accomplishment is much more likely to be interrupted, when one or two ligatures are applied on an artery without any subsequent division of it. With regard to the circumstances which occasion this difference, I shall consider them in the following chapter.

CHAPTER V.

ON THE IMPROPER FORM AND APPLICATION OF THE LIGATURE, AS TENDING TO PRODUCE SECONDARY HEMORRHAGE.

THE preceding chapters have, I think, afforded ample proof that every part of an artery is organized in a similar manner to the other soft parts of the body; and that its coats are susceptible of the same processes of adhesion, ulceration, &c. as the other parts are, when the same means of producing them have been employed. It follows, that the same precautions, which we take to secure the adhesion of other parts, should be observed, to effect it in an artery. But there is this difference in the cases; we endeavour to obtain union by the first intention in common parts, to remedy an accident or heal a wound; whereas, in the case of an artery, we perform an operation on it, to put it in the state of a simple wound, *i. e.* in a state in which adhesion may take place: and this operation consists in the application of the ligature, which, when properly applied, cuts through the internal and middle coats of the artery, keeps their cut surfaces in contact, and affords them an opportunity of uniting and cicatrizing, as other cut surfaces do, by the adhesive inflammation. The immediate suppression of the hemorrhage, which the ligature effects, is to be con-

sidered then, only as a primary and temporary part of its office; we are chiefly to consider its application in the more interesting and important view of an operation, which has for its object, not only the immediate suspension of the hemorrhage, but also the adhesion of the internal and middle coats of the artery, as the only permanent security against the return of the hemorrhage.

But it is well known that, generally speaking, we can only obtain union by the first intention in clean and simple incised wounds, consequently it is only in such wounds of the arterial coats that we can reasonably expect it; and hence, it is obvious, that we should take the utmost care, to use the ligature of the form, and to apply it in the manner most conducive to the formation of such a wound.

Having premised these general observations, which, I hope, appear sufficiently well founded, to serve as data, from which we may reason as to many of the causes of secondary hemorrhage, I shall now consider the manner in which the ligature, by its improper form or application, may give rise to secondary hemorrhage. It may with truth be asserted, that that part of surgery which relates to the securing of arteries, obtains a very inadequate degree of attention: provided that ligatures are ready, their size and form, whether completely flat or irregular, are, I believe, seldom attended to; nor does it appear that the degree of force employed in tying the artery, is often taken into consideration. Some surgeons, wishing to guard against the ligature's slipping off, tie it with

very considerable force; while others, apprehensive lest they should cut through the artery, or occasion too early a separation of the ligature, draw it only sufficiently tight, to prevent the escape of any blood. Now it appears highly improbable, that a broad, flat ligature should make such a wound in the internal and middle coats of an artery, as is most favourable to adhesion; because it is scarcely possible to tie it smoothly around the artery, which is very likely to be thrown into folds, or to be puckered by it, and, consequently, to have an irregular, bruised wound, made in its middle and internal coats. And even if it should make a proper wound, yet, by covering a considerable space of the external surface of the artery, it may destroy the very vessels which pass on it in their way to the cut surfaces of the internal and middle coats, and thereby render them incapable of inflaming: nor does it appear that anastomosing branches can supply this defect, for, if the branches which immediately supply the cut surfaces are bruised and compressed by the ligature, how is the blood from anastomosing branches to enter them? but admitting that such a ligature makes a proper wound, and that the wound unites, still it may cover that part of the external coat which is directly over the newly united part;* and consequently, as soon as it has occasioned ulceration through the ex-

* In many of the experiments with the ligature, the internal coagulum of blood being removed, and the extremity of the artery minutely examined, I found, that its internal and middle coats adhered *close above* the part, around which the ligature had been applied.

ternal coat, it will produce the same effect on the newly united parts, and of course, secondary hemorrhage.

If a ligature is of an irregular form,* the probability is, that it will cut through the internal and middle coats of an artery more completely at some parts, than at others; but from Experiment IV. related in Chapter III. it appears, that, to induce a sufficient degree of inflammation, to occasion an effusion of lymph from the internal surface of an artery, it is necessary that these coats should be completely cut through: this fact does not rest on the authority of that experiment alone, for in all my experiments with the ligature, which were examined soon after it had been applied, although the internal surface of the artery appeared inflamed a little way above the part at which it adhered, yet in no instance did it exhibit the appearance of lymph having been effused on it, except at the part which had been cut; and the point of adhesion was never more than a line's breadth: in short, the artery seemed to adhere only at its cut surfaces.†

* It is a fact, which I have had opportunities of observing, that, through inattention, a ligature is sometimes made flat at one part, triangular or nearly so at another, and so on alternately through its whole length.

† This fact is well illustrated by adverting to the opinion that Pouteau entertained of the effects of ligatures, and which opinion was founded on observations made on the state of the artery of which he has given a plate. Pouteau considered it to be proved with regard to ligatures, " que leur effet n'est point d'arrêter le " *sang au dessous du fil, ni immediatement sous le fil, mais dans la* " *partie du vaisseau excedente au dessous de la ligature.*" Melanges de Chirurgie, p. 322-3. Now as Mr. Pouteau recommended that

From these facts, I think we may fairly conclude, that if the ligature does not completely cut through the internal and middle coats all round the artery, adhesion cannot take place between its internal surfaces, and therefore secondary hemorrhage will take place as soon as the ligature has ulcerated through any part of the parietes of the artery; and that it will of course become more frequent and copious as the process of ulceration advances.

The observations which I have here made, will, undoubtedly, be especially verified, if such a ligature as I am alluding to, or perhaps any ligature, is applied by an operator, who is particularly careful not to tie the artery tight, lest he should cut through its coats, or occasion too speedy a separation of the ligature.

the surrounding parts should be included in the ligature with the artery; if we connect with this the state of the artery from which his opinion was formed, we shall immediately perceive, that the ligature had not cut through the internal and middle coats of the artery; that it had merely compressed its sides a little; and, consequently, no permanent obstruction was formed either above or immediately under the ligature; but *the cut edges of the extremity of the artery had united;* and yet in order that they might come into contact, and, in fact, to prevent the hemorrhage occasioned by the division of the artery, the ligature must have been applied tight enough, in the first instance, to bring the internal surfaces of the artery into contact, and to stop the flow of blood: this allowed the cut edges at the extremity of the artery to remain quietly in contact, and they united. But the artery could not unite immediately under the ligature because its middle and internal coats were not cut through: on the contrary, its canal appears to have been partially dilated again, the pressure made round it by the ligature not having been sufficient to prevent this effect.

Another circumstance with regard to the ligature, is its being applied so as to form an oval instead of a circle, by embracing the artery higher up on one side than the other: this, I am aware, will be more or less remedied in the act of tying, but yet in consequence of an artery being drawn out unevenly with the tenaculum, or, if it be entire, of the cellular membrane being more detached from it on one side than the other, this may sometimes happen; and it is obvious, that, in such a case, the cut edges can neither be so justly placed, nor so firmly kept in apposition, as they ought to be; they will, therefore, be more easily torn asunder, and the ulceration produced by the ligature will be much more likely to affect the recently united parts, and produce hemorrhage, if they escape it from other causes. I do not say that a ligature can be tied around an artery so as to form a complete oval; I mean to allude only to the deviation from a circle: now it appears from what has been already said, that it is only the cut surfaces which unite; any deviation therefore from a circle must be unfavourable to the exact and steady apposition of these parts. I think there can be little doubt, either as to the reality of the ligature being sometimes applied in that way, or as to the tendency of such an application of it to produce secondary hemorrhage.

It cannot reasonably be expected, that I should illustrate the opinions, which I have now offered, by cases; and perhaps it would not be very easy to confirm them by experiments on dogs, for whom Nature, with very little assistance, seems to do so much. If

however, they are allowed to be highly probable, and have a tendency to excite a greater degree of attention to this part of surgery, I shall not regret having ventured to bring them forward.

It may be expected that I should say, of what form the ligature ought to be made: and with what degree of force it should be tied. With regard to the former, I have little hesitation in saying, that I believe it is best to make it round, and very firm. As to the degree of force which should be used in tying it, I shall only observe, that every operator should be acquainted with the force necessary to cut through the internal and middle coats of an artery; but as this force is very slight, and the external coat of an artery is strong enough to allow the ligature to be tied tight, without its being cut through; it is better to tie the artery tighter than is necessary merely to cut through its inner coats, because we shall thereby more certainly keep the cut surfaces in contact; expedite the coming away of the ligature; and of course diminish the risk of the ulceration extending to the newly cicatrized part: nor does there appear to be any reason to fear, that the external coat may ulcerate through before the internal coats have adhered, since we see from the experiments, that their union is very soon effected. Instead, therefore, of this apprehension, let us rather direct our attention to keep the limb as quiet as possible, and to guard against every means by which the adhesion may be destroyed.

There is yet another important consideration which it is necessary to notice here. I allude to the slip-

ping off of a ligature. It is well known that this accident has often happened; and it may be adduced in confirmation of the observations which I have offered, on the improper and careless application of the ligature; for however surgeons may endeavour to excuse themselves by referring it to the violent impulse of the blood;* I believe that a candid inquirer into the cause of it, will find a much more rational and satisfactory explanation, either from the clumsiness of the ligature, which prevented its lying compactly and securely round the artery; or from its not having been applied tight enough, lest it should cut through the coats of the artery too soon; or, finally, from its having that very insecure hold of the artery, which the deviation from the circular application, above alluded to, must necessarily occasion. It is obvious that these causes may be variously combined in the same case, and if one be

* To resist the impulse of the blood and prevent its escape, is the very first object for which we apply a ligature on an artery, and there can be no doubt that, when properly applied, it is fully adequate to that purpose; for we are not to suppose that the blood continues to be impelled against the extremity of the artery, with the same impetuosity that it circulated through that artery, previous to its being tied: the preceding chapter affords many proofs that it does not. I shall not recapitulate them here, but shall only beg leave to remind the reader, of the immediate determination of blood to the collateral branches; and that it has been observed, that there is no pulsation at, or for some space above, the tied extremity of the artery: nor let it be said that this last circumstance depends on the retraction of the artery, for the fact is, that the principal retraction of the artery takes place as soon as it is divided, and if there is any afterwards, it is certainly very little and very gradual. See also Note R.

adequate to occasion the slipping off of the ligature; how much more likely is that event to happen, when they are so combined.

From a variety of facts interspersed through these chapters, which it would be tedious and unnecessary to recapitulate, I am convinced that if an artery is tied in the manner which I have suggested, there will be little reason to fear its being pushed off by the impulse of the blood; but if we wish for greater security than that mode of tying can give, we may have recourse to one of the modes of practice formerly recommended by Dionis.*

The observations which I have hitherto made on secondary hemorrhage, refer to the application of a ligature on the extremity of a divided artery, or to cases in which two ligatures have been applied on an artery, and the intermediate portion divided. I shall now consider the circumstances under which it occurs from an artery that has been tied with a single ligature without any subsequent division of the vessel. On this subject much has lately been said about the retraction of the artery, to which the secondary hemorrhage has been

* .... en pinçant le bout de l'artère avec un bec de corbin ou une pincette qui a un anneau pour serrer, qu'on appelle valet à patin; puis coulant sur l'instrument, jusques sur l'artère, un fil préparé et noué, on le sert d'un double nœud; et afin qu'il ne soit pas poussé hors de dessus le bout du vaisseau par les pulsations continuelles du sang artériel, il doit y avoir à un des bouts du fil une aiguille enfilée, qu'on passe à travers le corps du vaisseau, après quoi on assure la ligature par quelques nœuds. Operations de Chirurgie, Neuv. Dem. par M. Dionis.

almost wholly imputed;* but from what I have seen of arteries treated in this way, it appears difficult to conceive how retraction of the artery can have any effect in producing it, or even how it is possible that the artery can retract, when the ligature has been applied immediately around it, without including any of the surrounding parts; for although the ligature produces ulceration of the parts with which it is in immediate contact; yet, long before this process commences, an effusion of lymph has taken place around the parts of the artery near the ligature, and completely confines the artery to, and incorporates it with the surrounding parts. See Chap. IV. Experiment VIII. and pl. XIV. fig. 1.

I hope it will be remembered, that I am only discussing the causes of secondary hemorrhage from arteries treated in this way; as I by no means wish it to be understood, that I deny the advantage of an artery being allowed to retract, by dividing it after a ligature has been applied on it. It is well known, however, that many successful operations for aneurism have been performed, by applying a ligature on the artery without any subsequent division of it; and I think it highly probable, that if we could be minutely informed of the circumstances of those cases, in which repeated secondary hemorrhages have occurred when the operation has been thus performed, we should find the hemorrhages referable, either to a diseased state of the artery; to the various means which have been employed for guarding against hemorrhage, by contrivances to

* See note T.

compress a large portion of the artery, or for remedying it, if it should occur, by having a loose ligature above that which was tied; or, finally, to the fear of producing too speedy an ulceration of the artery;* in consequence of which the ligature has not been applied sufficiently tight to cut through the internal and middle coats, so as to fit them for adhesion; but, on the contrary, has occasioned a gradual ulceration through the coats of the artery, and, of course, produced hemorrhage, which has returned with greater violence as the ulceration advanced. To these causes may also be added those which have been suggested in the preceding part of this chapter; for they will operate at least with equal effect on an undivided artery.

If these observations are well founded, they certainly have a tendency to show, that there is not so important a difference, as far as relates to the production of secondary hemorrhage, between an artery's being tied with a single ligature, and its being tied with two, and divided between them: for the great advantage of the retraction of the divided artery within the cellular membrane seems to be, in a great measure, if not completely compensated, in the case of the undivided

* I believe it is an indubitable fact, that this was, for a long time, esteemed by many as one of the most important considerations in the operation for aneurism; it is therefore highly probable, that, in many instances, it occasioned the timid or imperfect mode of tying the artery, to which I have here alluded, and which, in a former part of this treatise, has, I trust, been satisfactorily shown to be highly unfavourable to the union of the internal surfaces of the artery, and, of course, conducive to secondary hemorrhage.

artery, by the speedy and profuse effusion of lymph, which takes place over and round the artery, at the part which has been tied; and which not only secures the portions of artery for some distance above and below the ligature, but, at first, covers even the ligature itself, which afterwards occasions ulceration through this layer of lymph. If it be said that actual experience drawn from the human subject, is in direct opposition to this conclusion; I would refer to the treatment which an artery, tied with a single ligature, has generally undergone, as detailed in the preceding pages. And I must candidly confess myself disposed to believe, that the principal, if not the only difference, in what relates to the production of secondary hemorrhage, between an artery which is tied with two ligatures and divided between them, and one which is tied with a single ligature, consists in this, that, in the former, the artery is tied close to the part at which its connexion with the surrounding cellular membrane is complete; but, in the latter, a considerable portion of the artery is detached from the surrounding cellular membrane, and the ligature applied perhaps in the center of this detached portion; or if even it be applied at the upper end, still there remains a considerable portion of detached artery below it: now when we consider, that the arteries receive their vessels from the surrounding cellular membrane, it must be evident, that if we deprive it of these vessels, it cannot undergo those changes which depend on vascularity, *viz.* inflammation and adhesion; and, consequently, the ligature cannot produce those effects on which the success of the operation depends, but the portion of artery

dying and bursting or sloughing, hemorrhage takes place: if the ligature be applied on the center of the detached portion of the artery, when the artery gives way, the hemorrhage will proceed both from the upper and lower portions; but if it be applied on the vessel at its connexion with the surrounding cellular membrane, either above or below, the hemorrhage will then proceed from only one part of the artery, which will be that, which has the detached portion of the artery for its extremity. As the hemorrhage will supervene as soon as the smallest part of the artery has given way, of course, it will frequently return, and perhaps even prove fatal, before the artery is divided into two distinct portions, and hence we almost always find the secondary hemorrhage described, as issuing from the artery immediately under the ligature.

The fact, that the artery is very soon covered and surrounded with lymph at the part which has been tied, forms no objection to this reasoning, for the lymph, which surrounds the artery, is furnished by the inflamed vessels of the cellular membrane; but as the arteries which supplied the coats of the arterial trunks have been completely divided, they cannot inflame as far as that division has extended, and, consequently, a ligature applied on that part cannot produce inflammation and adhesion of its internal surface. It is possible, that, in process of time, the vascularity of the artery might be restored by vessels from the cellular membrane, passing through the lymph with which the artery is surrounded, and extending to its tunics; but before it can be effected, the artery has given way,

and secondary hemorrhage has come on. I very much doubt, if an artery tied with a single ligature, without a greater detachment of it from the surrounding parts, than the ligature necessarily occasioned, would be more subject to secondary hemorrhage, than the artery of an amputated limb, or one on which two ligatures had been applied, and the intermediate portion divided. But as it is extremely difficult to avoid detaching the artery, and there is no advantage gained by applying a single ligature, it is, undoubtedly, safest and best to apply two ligatures, and to divide the artery between them.

Although I scarcely conceive it necessary to notice the injudicious practice of including in the ligature any of the parts surrounding an artery, yet, as I have met with a case, which may, I think, be introduced here with considerable effect, in illustrating the greater tendency of that mode of tying arteries to produce secondary hemorrhage than the other, I shall avail myself of this opportunity of quoting it. The case is related by Pouteau in the following words: " Au " mois de Septembre 1756, Je liai l'artère crurale " d'un chien de moyenne grosseur par une ligature " qui embrassoit aussi le Nerf du même nom: l'artère " ne fut ouverte en aucune façon, et on abandonna " l'animal à lui même, le quatrième jour il survint une " hémorrhagie qui s'arrêta sans aucun secours, *elle re-* " *parut le lendemain, et fut si grande que l'animal* " *mourut.* En fendant l'artère suivant sa longueur, " *je la trouvai ouverte, à sa partie anterieure,* immedi- " atement sous les fils de la ligature; il y avoit dans " sa cavité un caillot d'un rouge pâle, d'une consis-

" tence moyenne et fait en forme de fuseau: *l'extrémité*
" *superieure de ce caillot flottoit dans l'artère au dessus*
" *de la ligature; la portion moyenne étoit légérement ad-*
" *hérente à la partie posterieure de l'artère qui étoit sous*
" *la ligature;* la portion inferieure qui étoit la plus
" fine, flottoit dans l'artère *au dessous* de la ligature;
" ce coagulum avoit en tout quatre lignes de longueur,
" et moins d'une ligne de diametre, dans sa plus
" grande epaisseure."*

We have seen by the experiments, related in the preceding chapter, how extremely difficult it is to produce secondary hemorrhage in dogs, when a ligature or ligatures are applied immediately around their arteries; but in this experiment, in which the nerve and, no doubt, some cellular membrane were included with the artery, secondary hemorrhage was very soon produced, and to an extent which proved fatal.

It appears highly probable from the result and examination of this experiment, that the internal and middle coats of the artery had not been cut through by the ligature; for, if they had, and the ligature had been applied sufficiently tight to keep them in contact, there can be no doubt, that they would have adhered to each other long before the fourth day, when we find the hemorrhage first occurred. But in consequence of that mode of applying the ligature, instead of its producing this effect, we find, that it occasioned ulceration through the anterior part of the artery, which must, no doubt, have been exposed in the ope-

* Pouteau, Melanges de Chirurgie, p. 30.

ration, and with which, therefore, it was directly in contact: this ulceration was small at first; and hence the first hemorrhage ceased of itself; but having become more extensive by the day following, a hemorrhage came on, which proved fatal. It would seem, that the ligature had cut through the internal and middle coats of the artery sufficiently at the posterior part, to occasion such an adhesive state of their edges, as could detain a small quantity of the blood, which was passing through it, and hence the formation of the slender coagulum which Pouteau found in its canal, slightly adhering to the internal surface where the ligature had been applied.

It certainly appears strange that such a man as Mr. Pouteau appears to have been, from the accuracy of his observations, and his fidelity in detailing them, of which this work has afforded many instances, instead of directing his attention, in this instance, to the circumstances which had really caused the hemorrhage, should have observed, with regard to it, that the clot was insufficient to stop the hemorrhage, and that this gave us reason to presume, that it is almost always so: thus availing himself of this inapplicable experiment, to combat Petit's doctrine of the suppression of hemorrhage by the formation of a clot.

There is yet another cause of secondary hemorrhage, which, although I have hinted at it once or twice in the preceding parts of this treatise, I have not yet represented it in the important point of view which it ought to be. I allude to the sudden separation or lace-

ration of the recently united parts of an artery by premature and extraordinary exertions of the patient.

That newly cicatrized wounds may easily be torn asunder, for a certain time after their union, a sufficient number of proofs might be adduced, if any were required, from the operation for the hare lip; but in these, and in other instances of disunited wounds in fleshy parts, the united surfaces had been more or less broad, and, of course, their adhesion proportionably strong; whereas in the case of a recently united artery, the cicatrized part is a mere line, and, consequently, weak, and easily torn through: it is, therefore, of the utmost importance to keep the limb, a large artery of which has been tied, in a state of the most perfect rest, and to prohibit and guard, as much as possible, against the patient's making any sudden or great exertion. In the case of amputation which gave rise to Petit's invention for compressing divided arteries, secondary hemorrhage was brought on, on the twenty-first day after the operation, by the patient's raising himself suddenly and sitting up in bed. On this subject Petit makes the following observation: "Mais dans tous les "cas, il est d'une nécessité absolue de procurer un "très grand repos au malade et à la partie coupée:"* in which, however, he seems rather to have had in view the perfect formation of the clot, for he afterwards adds: "parce qu'en changeant de situation, "l'on troubleroit la formation du Caillot."† But the remark is not the less valuable and worthy of atten-

* Petit, Memoires de l'Acad. &c. de l'année 1732.

† Ibid. ibid.

tion; nor does this allusion to the clot prove that he was ignorant of the state of the extremity of the artery; for in a former memoir, after describing how he conceived the particular figure of the clot, formed in an artery that had been tied, would prevent hemorrhage, even though the extremity of the artery should ulcerate; he adds: "Ce n'est pas la même chose, "quand quelque Convulsion, ou quelques autres "mouvemens violens de la part du malade, sont la "cause de la separation de la ligature; car cette se-"paration se fait alors avant la parfaite clôture du "vaisseau, et de plus, le Caillot malgré sa figure est "poussé avec tant de violence, que non seulement, il "sort, mais qu'il detruit même en passant tout ce "qu'il y a de Réunion commencée, et l'ouverture du "vaisseau, aussi large qu'auparavant laisse darder le "sang comme le premier Jour."*

* Petit, Mem. de l'Acad. &c. de l'année 1731.

NOTES.

Note A. Page 33.

Petit mentions experiments made on dogs by Rabel, Piot, and others, to prove the power of their styptics in stopping hemorrhages. In many instances, he says, they succeeded; but he adds: " Plusieurs aussi " moururent d'hemorrhagie, je les disséquai et je " trouvois que l'artère au lieu d'être totalement coupée " n'étoit que simplement ouverte." Petit, chirurgien, Troisieme Mem. &c. Memoires de l'Acad. &c. de l'année 1735, p. 594.

Note B. Page 86.

In the memoirs of the Academy of Sciences for the year 1732, there is a paper by Monsieur Petit, the physician, in which he gives an historical view of the various means that have been employed, at different times, for the suppression of hemorrhage. In his account of the practice of Hippocrates, Galen, and Celsus, after mentioning that they used astringents, absorbents, &c. he adds: " et dans un sang très coulant " et poussé avec force, *ils ont quelquefois coupés en tra-* " *vers les vaisseaux qui ne l'étoit pas*, et pour lors les " extrémités des ces vaisseaux, se retirent de chaque

" côté au dedans des chairs par leur ressort. Ces " mêmes chairs comprimées contres les vaisseaux par " des compresses les obligent de se boucher eux- " mêmes. *Si la playe dans la quelle le vaisseau étoit " ouvert, étoit faite par un instrument tranchant, ils cou- " soient les lèvres de la playe, qui venant à se rejoindre " l'une avec l'autre, bouchoit l'embouchure du vaisseau.*"

Note C. Page 114.

Mr. J. Bell, after noticing an interesting case from Deschamps, says: " This case satisfies us of a fact " which is proved also by other accidents, (as the " aneurism from bleeding), that an artery, wounded " with a small and slit-like wound, though fairly cut, " will yet preserve its pulse, and will not bleed." J. Bell's Principles of Surgery, p. 434-5.

Note D. Page 115.

This circular appearance of transverse wounds will, of course, be lost, if the wound is very considerable. It appears to have been a very old observation, that wounds of arteries are circular; it has been noticed by Wiseman, Petit, Monro, and Haller; but I believe, that the appearance is confined to punctures or small transverse wounds of the artery, and depends chiefly on the retraction of the divided fibres. A circular wound in an artery, must, as in every other part, be the most unfavourable for reunion, and the fact, that transverse punctures produce circular wounds, may alone afford a

satisfactory explanation of a circumstance mentioned by Mr. J. Bell: in speaking of simple slanting wounds of arteries made by the sword, he says: " they were " in plain terms cured by adhesion;" . . . . . but " when, in place of being a simple wound, the " artery was punctured, the consequences were often " fatal." P. 443, Principles of Surgery.

Note E. Page 115.

Petit, speaking of the treatment of a wounded artery, observes: " Cette espèce de Compression qui " n'abolit point la fonction du vaisseau *ne peut guères* " *avoir lieu que dans le cas où l'ouverture de l'artère est* " *médiocre*, car lorsque le vaisseau est considerablement " ouvert, le caillot ne pouvant alors que très dif- " ficilement faire canal avec ce qui en reste, *il faut* " *presque toujours agir de la même manière que si le* " *vaisseau étoit totalement coupé*, c'est à dire, qu'il faut " entièrement boucher le canal, et empêcher que le " sang y passe; si l'on vouloit dans ce cas comprimer " foiblement, le sang chasseroit continuellement le " caillot, et l'hémorrhagie subsisteroit. Il n'en est " pas de même lorsqu'il n'y a que le quart, et encore " mieux le cinquième ou la sixième partie du vaisseau " qui soit ouverte; alors le caillot pouvant être soutenu " par un bandage modéré ne sera point chassé, et " bouchera l'ouverture pendant que le sang coulera " dans le vaisseau presque à l'ordinaire." Petit, Mémoires de l'Acad. Roy. des Sciences de l'année 1735.

Note F. Page 116.

There can be no doubt, that this tubercle of lymph is formed in every instance in which an artery is wounded; and that although a laceration of it, at its weakest part, occasions the formation of aneurism, as has been already described, yet that, by an accurate examination, it may always be found adhering to the artery: thus Trew, in giving an account of an operation for spurious aneurism, at which he was present, after observing that the operator cut into the tumour, and cleared out coagula and grumous blood, adds: "Posthæc magis magisque totam cavitatem à grumis "digitorum ope purgabat, *ac denique, quendam paulo* "*firmius ad locum arteriæ adhærentem, et aliter confor-*" *matum protrahebat*, illi, quam Domini Janenses in "casu superius exposito offenderunt, valde similem, "*articulum digiti magnitudine æquantem, sanguine con-*" *grumato pallidiorem et quasi membranosum.*" Trew, Aneur. spur. Lauth. Collect. p. 562.

In this quotation, mention is made of this tubercle of lymph adhering to the artery in two instances, in which the operation for aneurism had been performed. The case to which Trew alludes, is one which had just before been quoted from Teichmeyer and Hambergerus, in which it is said, that after the aneurismal sac was cut open, and the coagulated and some fetid blood cleared out, "Apparuit tunc globus ex carne "membranosus superficiei inæqualis, arteriæ adhæ-" rens, diametri duorum digitorum." Lauth. Collect. p. 554.

Note G. Page 118.

Sacco scilicet quem dicunt aneurismati cum sanguis effusus obducitur, qui tamen organicum non prodit textum, et nullatenus a dilatatâ, ut communiter credunt, arteriâ ipsâ originem suam trahit; *eam enim in quocunque aneurismate spurio, naturalem suum retinere diametrum*, et vulnusculum ipsum sub tumoris formatione eandem quam sub primo inflictu acciperat, servare extensionem, tam aliorum, inter quos Cel. Teichmeyer, Alexander, et Don. Monro, De Haen, Aerel et Richter nominâsse sufficiat, quam mea ipsa in vivis operationi subjectis, atque etiam alio post operationem extincto experientia edocuit. Murray, Lauth. Collect. p. 502.

Note H. Page 118.

Lancisius, after speaking of the causes which prevent the reunion of wounds in arteries, says: "cum statim ac coire cœperint, sanguinis impulsu divulsa, removeantur *glutine disjuncto* adhuc molli et infirmo. Lancisius, Lauth. Collect. p. 16. prop. 11.

Murray also, after giving a similar account, or rather quoting Petit's description of the manner in which hemorrhage from a wounded artery is stopped, says: "Nonnunquam vero istud coagulum in ipsâ "arteriæ aperturâ *non hæret, sed extra* illam, quando "major sanguinis copia effusa in cellulositate vas

" revinciente congeriture, tumque operculum illud in-
" organicum, latius extensum, firmius licet a circum-
" jacentibus partibus et telâ cellulari immixtâ ful-
" mentum accipiat, minus flumini resistere potest.
" Rivo scilicet extrorsum protrudente, in membranâ
" adsitâ laxatâ, quum ipsius vasis parietes minorem
" jam persentiant pressionem, cavum quoddam quasi
" exculpitur a coagulato nigro sanguine indies ampli-
" ficandum. Sed si urgenti flumini minus cedit tumor,
" rumpitur pseudomembrana et sanguinis exuberans
" quantitas quæ imprimis saccum distenderat extra
" saccum effunditur." Murray de Aneurismat. Lauth. Collect. p. 503.

Note I. Page 119.

Ex his aperte intelligitur arteriarum vulnera curationem facile, obductâ cicatrice, admissura si eorum labia inter se admota atque conjuncta, probe aptentur, ac diutius in eo situ contineantur, interim vero unà curatur, ne sanguis ad affectam partem impellat, vel saltem ut ipsius impetus quoad fieri poterit infringatur ac debilitetur: hac enim ratione succus qui ex tunicarum fibris sponte manat nutritioni idoneus sensim coalescet, ac inflictam plagam glutinabit. Lancisius, Lauth. Collect. p. 15. prop. 11.

Note J. Page 119.

Garengeot, after describing the manner of dressing a wounded artery with chewed paper, compresses,

&c. adds: " Quand la charpie est tombée, et le petit " morceau de papier maché, on apperçoit *à l'artère* " *un endroit blanchâtre où le battement paroit plus sen-* " *sible; c'est là l'endroit où étoit la division qu'il ne faut* " *pas laisser long temps decouvert.*" Traité des Operations, vol. III. p. 248.

On this subject Murray observes: " Sed neque " desunt exempla vulnerum arteriæ ejusdem recen- " tium, et nullo Aneurysmate conjunctorum, solâ " compressione et aptâ cæternum deligatione consoli- " datorum." Murray, Lauth. Collect. p. 540.

" In recentissimâ arteriæ vulneratione, nullo adhuc " formato aneurysmate, deligatio apta ab initio eo " lubentius tentanda, cum millena testentur exempla, " arterias lanceolâ apertas hoc modo facillime fuisse " consolidatas." Ibid. p. 543.

After noticing many interesting facts on this subject, Trew makes the following observation: " Cæterum " nemo de perfectione ejusmodi curationis dubitabit " qui considerat omnium consensu, non solum possi- " bile declaratum, *verum etiam experientiâ satis compro-* " *batum esse, arteriæ vulnus solâ compressione sanari* " *posse*, quamdiu sanguis extravasatus fluxilis adhuc " est et in alvum suum reduci potest." Trew, Lauth. Collect. p. 580. The latter part of this quotation is true, though, perhaps, not exactly in the sense which he means; for, with regard to the healing being possible, " quamdiu sanguis, &c." he must be understood merely that it is possible, if the proper means are used, in the recent state of the wound; and not

that the return of the extravasted blood into the artery could be effected, or could influence its reunion.

Note K. Page 119.

The various parts of the following very interesting case, will be found to illustrate and confirm many of the most important parts of this chapter. It is not introduced for the purpose of recommending this mode of treating wounded arteries, but that the necessity for continuing the pressure on the wounded part for some time after it has healed, may be rendered sufficiently obvious, and that the uncertainty of this mode of treating them may be more manifest.

In order to be as concise as possible, I have quoted the case only partially, and hope, that the importance of it, the authority from which it is derived, and its being so very apposite to our present purpose, will render any apology for its length unnecessary. " L'Aneurisme dont il étoit question, étoit causé par " l'ouverture de l'artère à l'occasion d'une saignée " . . . . il" (the patient) " nous apprit que dans l'instant " de la saignée le sang avoit dardé par sécousses, que " le chirurgien avoit eu beaucoup de peine à l'arrêter; " qu'il avoit doublé et triplé les compresses et le ban- " dage, qu'il lui avoit recommendé le Repos, surtout " celui du bras; qu'il lui fit plusieurs saignées en con- " sequence, et lui prescrivit un regime très severe " . . . . aussi fit il ce qu'il put pour y remedier, et il

" eut l'avantage de réussir. *L'artère et la plaie exté-*
" *rieure* se fermèrent; le malade étoit en voie de
" guérison, et il seroit guéri, selon toute apparence,
" s'il avoit continué les remèdes, mais au bout *de*
" *douze jours*, il quitta son bandage. Deux ou trois
" jours après l'avoir quitté, il s'apperçut *d'une petite*
" *grosseur molle* et accompagnée de pulsation, mais
" qui rentroit en la pressant. Ayant fait un effort huit
" ou dix jours après, il sentit de la douleur à son
" bras; sur le champs la petite tumeur devint beau-
" coup plus grosse." The bandages, &c. were again applied, but the tumour continued to increase. Petit operated on the man, and says: " Lorsque la peau
" fut suffisamment ouverte je trouvois beaucoup de
" sang très noir" and a succession of coagula, which were gradually less and less black, the nearer he approached to the artery, but he adds, they were " si
" ferme et si solide que ceux qui n'ont point fait, ou
" vu faire l'opération de cette espèce d'aneurisme,
" auront pu prendre cet amas de caillots pour de la
" chair, s'ils ne s'en fussent rapportés qu'à sa couleur
" et à sa consistence. Je passai mon doigt autour de
" cette masse de caillots, je la détachai entièrement
" *et avec facilité, excepté à l'endroit placé sur l'ouver-*
" *ture de l'artère, à la quelle, elle étoit fort adhérente;*
" ce fut alors que le corps de l'artère parut à décou-
" vert de la longueur d'un pouce. Dans le milieu de
" cette étendue étoit l'ouverture ou l'incision qu'avoit
" fait la lancette; cette incision qui étoit oblique
" avoit au moins la longueur de trois lignes." . . . .
He found that the coagula differed in their degree of solidity. " *Le plus dur* couvroit immediatement
" l'ouverture de l'artère, *le sang continuellement poussé*

" *contre ce caillot, lorsqu'il étoit encore trop mou pour*
" *lui résister, en avoit formé un espèce de poche ou ap-*
" *pendice*, dans la quelle le sang entroit, et de la quelle
" à chaque pulsation il sortoit en partie et rentroit dans
" l'artère, de la même manière que le sang entre et
" sorte de la poche qui forme l'aneurisme par dilata-
" tion. *Cette appendice étoit aussi grande que la coquille*
" *d'une grosse noisette; et elle étoit fort adhérente au*
" *bords de l'ouverture, et à la partie extérieure de l'ar-*
" *tère même.* Sa surface interne étoit lisse et polie,
" comme l'intérieure de tous les vaisseaux sanguins.
" Sa surface extérieure étoit adhérente avec le se-
" cond caillot. Le caillot du malade dont il s'agit
" avoit deja de fortes adhérences avec les bords et le
" vassinage de l'ouverture; il avoit assez de solidité
" pour résister aux impulsions du sang, et il y a
" résisté tant qu'elles ont été moderées, et que
" le caillot a été soutenu par le bandage," but the not having used the necessary precautions long enough,
" ce caillot encore trop foible, n'étant plus soutenu a
" été forcé d'obéir à l'impulsion du sang, qui l'a étendu
" peu à peu et en a formé la poche. En faisant l'opé-
" ration j'ai trouvé *cette poche ou caillot* encore adhé-
" rente à toute la circonference de l'ouverture de l'ar-
" tère excepté à un point du quel il n'avoit été detaché
" que par l'effort considérable que fit le malade douze
" jours après avoir quitté son bandage. C'est par ce
" point de séparation que sortit le sang qui forma le
" second caillot, et c'est par cette ouverture bouchée
" par ce second caillot, mais rénouvellée à sept ou huit
" differentes réprises éloignées de plusieurs jours les
" unes des autres, qu'est sorti le sang qui a formé les

" septs ou huits caillots qui composoient la tumeur. " Petit, Mém. de l'Acad. Roy. des Sciences de l'année " 1736, 8vo. edit. p. 350, &c."

Note L. Page 119.

It is unnecessary for me to point out the difficulty which must attend an attempt to compress a wounded artery, so as to keep its lips in contact, and at the same time neither obliterate its canal, obstruct the circulation through the limb, nor affect the return of blood by the veins, so as to produce tumefaction, and the well known train of evils thence ensuing. It is sufficiently obvious, that the difficulty will not only be very great in every case, but that in some parts of very muscular or fat people, it will be absolutely impossible.

I request the reader will refer to the commencement of the passage, quoted from Petit in note E. Murray also informs us, that if too much pressure is made, the artery will be obliterated, and if " qualis " ad scopum obtinendum requiritur," the patient is in constant danger of fatal hemorrhage. The same author in speaking of what he calls the aneurysma consecutivum says, that if the bandages which had been applied to suppress the hemorrhage from a wounded artery are removed " antequam ipsæ vasculi membranæ " coalescerunt; vel æger nimis cito articulum movere " incipit, guttulæ sanguinis paulatim per aperturam " minorem vasis elabuntur." Murray Lauth. Collect. p. 502.

Note M. Page 147.

Even this fact has been most accurately described by Morand, and in justice to him, as well as to accomplish the important object of showing, that the same circumstances take place in the arteries of the human subject, as in those of brutes, I shall quote his account of it.

After describing the state of the coagulum in an amputated limb to be just such as Petit had said it was, and, indeed, giving a similar plate of it, he says: "Dans cet état, il represente assez bien la moitié d'un "fuseau," and proceeds to explain, that it has this figure in consequence of the blood at the extremity of the artery being most at rest, and forming the thickest part, whereas towards the upper part of the vessel the coagulum is smaller and pointed, because the blood is there more in motion. He adds: "Tel est l'état du "caillot qu'on trouve dans l'artère les premières jours "après l'amputation, mais le sang cessant peu-à-peu "d'aborder l'extrémité du vaisseau qui s'est cicatrisé "par l'applatissement ou le froncement; en faisant "route par les embouchures des vaisseaux collateraux; "les parois de l'artère s'approchent de plus en plus de "son axe, le vaisseau en se rétrécissant* au dessus "du bout cicatrisé, devient un cone dont la point est

* Morand seems to have used "rétrécissant" here to signify contracting.

" la cicatrice, et le caillot comprimé devient vers la " cicatrice un peu plus pointu qu'il n'étoit; enfin la " capacité de l'artère s'oblitère tout à fait dans une " étendue plus ou moins grande; et degénère en une " espèce de ligament; et comme le caillot a toujours " été serré de plus en plus de la pointe du cone vers la " base, il s'amincit peu-à-peu et s'anéantit par les " suites." Morand, Mém. de l'Acad. Roy. des Sciences, &c. de l'année 1736."

Note N. Page 159.

Filo interrupi arteriam aliquam in mesenterio, continuo sanguis quievit in arteria: et globuli numerosi in medio trunculo *absque ullo ejus tumore ad locum vinculi usque congesti adparuerunt.* Trunci ligati partem cordi propriorem detexi, *vidi in ligatum ramum sanguinem nullum subire, neque contra quiescentem sanguinem niti, omnemque in alium ramum declinare.— Sensim vero de arteriâ ligatâ sanguis collectus ita refugit ut nullus supra vinculum sanguis maneret,* sub lino vero copiosior et stagnans superesse. Halleri Op. Min. vol. I. exp. 54. This experiment was repeated thrice, and Haller observes: " Experimentum tamen 54 " ostendit obstructas arterias minime eâ ratione qua " plerique theoriæ medicæ auctores scripserant intu- " mescere et distendi; et sanguinem potius qui com- " muni cordis vi emittitur, relictis et desertis vasis quæ " immeabilia resistunt, in ea vasa transire, quæ li- " bera, undam à corde advenientem admittunt."

Note O. Page 159.

Arteriam grandiorem diu consideravi. Cum primum oculum adhiberem, membrana duplo, quam lumen in axe crassior fuit; nempe lumen fuit ad membranas utrinque accumbentes, uti tertia pars diametri ad totam diametrum. Verum ea crassities mutabilis est. Celeriori paulatim sanguinis motu nato, sensim parietum crassities diminuta est, et lumen auctum, ut demum quadruplo, membranarum crassitiem superaret. Halleri Oper. Minor. Exp. 92.

9°. Diversam rationem in luminis ad parietes ratione esse, et nonnunquam multum superare parietes maxime in debili animale, deinde æquari, suscitato sanguinis circulo, tandem superare lumen. Ibid. page 88.

Note P. Page 159.

Quand ces obstacles bouchent quelques vaisseaux, le sang doit se détourner, et se jetter dans les tuyaux lateraux; c'est ce qui est également prouvé par le témoignage des yeux, de l'expérience, et de la raison. Dans un animal vivant donc, si on examine les vaisseaux avec le microscope, on voit que le sang arrêté dans un filet artériel se jette avec plus de force dans les tuyaux voisins. Lorsqu'on lie une grosse branche, les branches voisines battent avec plus de force. J'ai

lié, dit Schwenke, une artère, il passoit plus de sang par les vaisseaux les plus proches; *ceux qui auparavant se déroboient aux yeux devient sensibles;* une artère étant liée, dit le même auteur, un rameau lateral, et fort petit devient quelquefois egal à l'artère qu'on a liée. Senac, Traité du Cœur.

As it is to be wished, that when an experiment has been once performed, and found not to lead to any useful conclusion, it should never be repeated, I hope I shall be excused for introducing here the following quotation, which Senac has given from Van Swieten " Ayant ouvert, dit il, (Van Swieten) le ventre " d'un chien, je liai le tronc de l'aorte déscendante; " le sang des parties inférieures poussé par les efforts " de l'animal rémontoient vers le cœur avec plus de " force, mais l'aorte étant liée il ne pouvoit pas réve- " nir une seule goutte dans ces parties; l'animal " étoit extrèmement agité, les palpitations du cœur " étoient violentes, les yeux couvertes de sang se jet- " toient pour ainsi dire hors de la tête; la langue gon- " flée de même par le sang, sortoit de la gueule, qui " étoit rempli d'écume; la mort suivit bientôt ces " violens mouvemens." Senac, Traité du Cœur.

Note Q. Page 163.

It is with singular pleasure that I quote the following very interesting case from Petit, because it points out, that the changes, produced in an artery in consequence of an obstruction of the circulation through it, are precisely the same in man as in brutes; but in

this instance it appears to have been ultimately attended with fatal consequences. There are, however, many passages in the history of the case, which point out, that the man was intemperate. It may, therefore, be doubted whether his death should be wholly attributed to the effects which finally resulted from that obstruction: on the contrary, it is not unreasonable to suppose, that rigid temperance and early attention to the symptoms with which he was affected, might have preserved his life.

The case is as follows: a man had an aneurism, of the size of a pigeon's egg, on the right side, just under the angle of the lower jaw. Blood-letting and strict regimen were ordered; and exercise was forbidden. In three months the tumour diminished to half its size, and, although he then lived freely, it finally disappeared. At the end of two or three years, Petit felt "un petit nœud, ce nœud étoit "fort dur." The disease had left no other inconvenience, than that of occasioning the man to pronounce with a little difficulty, "de begayer un "peu et d'avoir la bouche habituellement remplié "de salive." Seven years passed away without any accident, but it was easy to perceive, "que sa "bouche étoit innondée d'une plus grande quantité "de salive, et que la pronunciation étoit plus dif-"ficile." About this time he was seized with apoplexy, of which he died in a few days. "On avoit "observé dans les trois ou quatre jours qui avoient "précédé cette attaque, qu'il étoit comme une per-"sonne ivre, qu'il ne raisonnoit pas juste, et que

" d'une moment à l'autre il ne se souvenoit pas de ce " qu'il venoit de dire ou faire."

On examination after death, Petit found: " Le " côté droit du cerveau étoit couvert d'une sérocité " sanguinolente, sous cet épanchement le cerveau " étoit sain, il n'y avoit aucun épanchement à l'exté- " rieur du coté opposé, mais en ouvrant le ventricule " supérieur, il en sortit environ cinq ou six onces de " sang dissous, et il resta un caillot de sang coagulé, " de la grosseur d'un petit œuf de poule, &c. cette " concretion de sang cachoit une ample et profonde " crevasse qui s'étoit faite dans la substance même du " cerveau à l'endroit désigné. Du coté gauche, c'est " à dire, du même côté où tout ce desordre s'étoit " opéré, *l'artère carotide, et les branches qui en pren-* " *nent naissance, nous ont paru avoir un tiers plus de* " *calibre que dans l'état naturel* . . . . . l'artère carotide " droit étoit *complètement oblitérée depuis sa séparation* " *de l'artère souclavière droite jusqu'à sa division en* " *deux branches principales*, ce qui répond à peu près à " l'angle de la machoire inférieure; en se bouchant " tout-à-fait, cette artère qui est ordinairement grosse " comme le bout du petit doigt, *s'étoit convertie en un* " *cordon grêle*, dans l'intérieur du quel on ne distin- " guoit aucune trace de conduit, *et ce cordon pouvoit* " *avoir deux lignes de diamètre.* Il y avoit dans le bas " de cette artère, precisement à l'endroit où elle nait " de la souclaviere droite, un petit sac aneurismal, " gros comme un noix muscade ordinaire, sa tunique " étoit fort mince, et l'intérieur de sa cavité étoit " rempli par une matière en partie graisseuse, en

" partie semblable à du sang desséché, on distinguoit " encore l'ouverture par la quelle, avant l'obliteration " de l'artère ce sac communiquoit avec la cavité de " l'artère elle-même; celle ouverture étoit fort petite. " Enfin, à la place de la tumeur ci-dessus décrite, il " se trouvoit un nœud dur, oblong, gros comme le " noyau d'une olive, et qui n'avoit aucune cavité à " l'intérieur." Petit, Chirurg. Mém. de l'Acad. Roy. des Sciences de l'année 1765, 8vo edit. p. 758—773.

Note R. Page 163.

I believe that this fact has never been denied or even doubted by any one except Monsieur Maunoir, who says: " Il ne faut pas penser, comme on l'a " avancé, que quelque temps après une opération " d'aneurisme qui aura réussie, on puisse trouver les " artères collaterales supérieures au lieu de la ligature " augmentées *visiblement* dans leur diametre, parce " que cette augmentation, ne se borne pas à une, " deux, ou trois artères, mais se partage entre toutes " celles qui appartiennent au membre opéré, petites " et grosses en rémontant jusqu'à l'aorte." Maunoir, Mémoires sur l'aneurisme, p. 78. Contrast this note with Note P.

Note S. Page 163.

It is difficult to conceive how any one, who had observed the obliteration of an artery which had been

tied, could form an idea of the regeneration of the obliterated portion. Monsieur Maunoir, however, seems very sanguine on this subject, and relates the following examination of an experiment, which he made on the right carotid of a fox, by tying two ligatures on it, and cutting between them. " Cette artère " qui avoit été liée plus haut que la gauche, se termi- " noit à huit centimètres au dessus de la naissance de " la vertebrale par une extrémité arrondie, pleine " d'injection, et dont le diametre étoit semblable à " celui du reste de l'artère; *de cette extrémité mousse* " *partoit un très petit vaisseau d'un millemetre de dia-* " *metre*, ou environ, qui se dérigeoit vers le bout su- " périeur de l'artère coupée et s'y anastomosoit." The author does not say, that the small vessel, extending from one extremity of the artery to the other, was filled with injection; but adds: " Ce petit ra- " meau qui établit une communication entre les deux " bouts de l'artère coupée, ne presente il pas une faite " très extraordinaire, et d'après le quel, on pourrait " croire à la régéneration des artères? Nous voyons " que cette régéneration est très lente dans les nerfs; " *peut-être est elle encore plus lente dans les vaisseaux* " *sanguins;* peut-être n'est il pas aucune organe qui ne " soit plus ou moins susceptible de réproduction." Maunoir, Mémoires sur l'Aneurisme.

Mr. Maunoir observes, that the reproduction of arteries may be slower than that of nerves. But in the course of a short time after the artery has been tied, the circulation through the limb is completely re-established by the anastomosing vessels, so that the

necessity for the regeneration of the artery is completely done away; and so far from an obliterated portion of artery being restored after a great length of time, the fact invariably is, that, until the tied portion has become obliterated to the first branches, above and below it, the longer the period at which it is examined, after having been tied, the further advanced it is found to be in a process directly the reverse of regeneration, *i. e.* a process of contraction and obliteration.

Note T. Page 175.

Nous allons voir que cette différence* est considerable, et que les hémorrhagies secondaires doivent être attribuées à cette action rétractile des artères. Maunoir sur l'Aneu. &c. p. 9.

Les Hemorrhagies qui surviennent après l'operation de l'aneurisme, sont la suite de la rupture de l'artère sous la ligature, rupture qui est déterminée par cette tendance à la retraction des tuniques de l'artère mise en activité par la presence de la ligature.

On ne voit pas jamais d'hemorrhagie dans ces operations,† parce que l'artère est libre de se retirer

* The difference in the retraction of an artery in the dead and living states.

† Amputations.

dans les chairs, cette rétraction qui a toujours lieu, rend presque nulle l'action de la ligature sur l'artère. Ibid. p. 76, 77.

Que l'artère affectée d'aneurisme ressemble à la corde de violon; que la ligature appliquée sur cette artère entière est la cause affoiblissante, ou pour mieux dire, la cause irritante, qui augmentant sa tendance à se rétracter en cet endroit déterminera sa rupture. Et vice versa, il étoit facile de voir que l'artère fémorale liée dans l'amputation ne se rompoit pas, parce que la ligature ne pouvoit être une cause de rupture pour une artère libre de se retirer dans les chairs. Maunoir, Mémoires sur l'Aneurisme, &c. p. 83.

An artery that has been tied cannot, with propriety, be compared to a "corde de violon," and it would be as difficult for the author to show how a ligature can augment the tendency of an artery to retract. If it cut through the artery before it was confined by lymph, it might allow its tendency to retract to have effect; but it is difficult to conceive how it could increase that tendency. Nor is it easier to understand how the retraction of the artery should render "nulle "l'action de la ligature sur l'artère," although it is readily granted, that the retraction of the artery may greatly contribute to prevent secondary hemorrhage. The advantages of this retractile power in the arteries, were long ago noticed and even overrated by Senac. "C'est de ce raccourcissement, que depend les effets "des astringents, lorsqu'ils ferment les ouvertures des

"artères; ces vaisseaux en se raccourcissant appli-
"quent les bords séparés l'un à l'autre: de même
"dans les blessures, les artères coupées se raccour-
"cissent, et se cachent dans le tissu des chairs qui
"les compriment; c'est cette compression qui arrête
"le sang." Senac, sur le Cœur, vol. II. chap. vii. p. 201.

PLATE I.

Fig. 1.

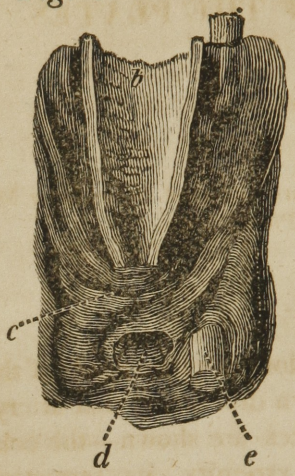


Fig. 2.

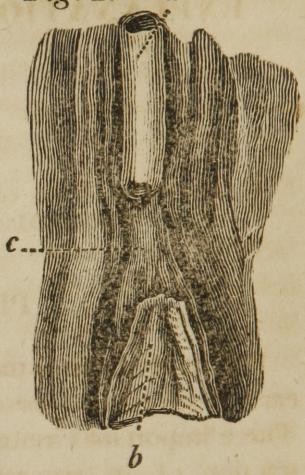
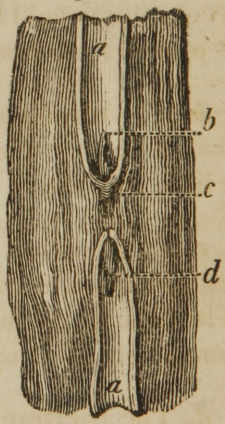


Fig. 3.

Fig. 4.



EXPLANATION OF THE PLATES.

N. B. The plates of this edition are engraved on wood by Mr. William Mason, of Philadelphia.

PLATE I.

Fig. 1. Represents the portion (next the head) of the carotid artery of a horse after a division of that artery. Three important circumstances are shown—the contraction of its truncated extremity, its retraction within its sheath, and its sheath and the continuous cellular membrane very extensively injected with blood; but the hemorrhage was so rapid, that before a coagulum could be formed in the canal of the sheath, it proved fatal. See Chap. I. Sect. II. Exp. I.

b. The carotid artery cut open, showing a contraction at the part where the division had been made, and a little way above it.

c. A portion of the sheath of the artery injected with blood, and within which the artery has retracted. The cellular membrane connected with the sheath is completely filled up with blood.

d. The aperture of the sheath through which the blood escaped from the artery.

e. e. The Parvagum.

Fig. 2. Represents the portion of the carotid artery of a horse that had been divided. Another circumstance, and one that is more important, in addition to the three shown in fig. 1, is represented, *viz.* a coagulum partly formed in the canal left in the sheath by the retraction of the artery, but not so perfectly as to stop the hemorrhage. See Chap. I. Sect. II. Exp. III.

a. The portion of the carotid artery next the head very much contracted, particularly at the divided part. This great contraction of the artery, in all probability, was not owing merely to the division of the artery, but was, in part, to be attributed to an operation, which it had undergone two or three days previous to its division, and by which its canal, between the head and the divided part, had been rendered impervious. It is probable, therefore, that the portion of artery near the obstructed part had already undergone some diminution of size: at any rate, as blood could not pass through the portion of artery *a*, which was between the obstructed part of the canal, and the point of division, it would be at perfect liberty to contract.

b. The portion of the carotid and its sheath next the heart cut open. The extremity of the artery much contracted; its sheath, and the cellular membrane surrounding it, very much filled with blood.

c. Points out, first, the distance between the retracted portions of the artery; secondly, a coagulum, partly formed, in the canal made in the sheath by the

retraction of the artery, which canal has been cut open to show this clot: for the sake of distinction, I shall hereafter call it *the external coagulum*. The external coagulum is of a conical figure, its base lying at the mouth of the portion of the artery *b*, but it is not of sufficient size to close the artery. It communicates with the blood effused between the artery and its sheath.

Fig. 3. Represents the superior portion of the femoral artery of a dog six hours after it had been divided. The external coagulum is completely formed. See Chap. I. Sect. II. Exp. X.

a. The portion of the femoral artery where it passes out of the abdomen under Poupart's ligament. The extremity of it is cut open to discover the exact point at which the artery terminates, and the external coagulum commences.

b. The external coagulum adhering to the end of the artery, and extending beyond it, supported by the sheath. It has for a certain space a slightly conical form, but just beyond its smallest part it swells out again to a considerable size, and turns forward at *e*, which marks the part where it was separated from the clot that lay in the wound, and covered both it and the extremity of the artery.

c c. The sheath separated from its artery by effused blood, but below it embraces the external coagulum.

d d. The end of the artery retracted some way within its sheath, and adhering to the external coagulum.

Next in order to Fig. 3, should follow Plates II. and III. Fig. 4. being misplaced.

Fig 4. Represents the femoral artery of a dog nine days after its division. The extremity of each portion of artery is closed with lymph, to which the internal coagulum adheres. The external coagulum of the inferior portion, and also the greater part of that of the superior, have been absorbed, or removed, by some natural means. See Chap. I. Sect. II. Exp. XIX.

a a. The portions of the artery cut open.

b d. The internal coagula of blood, neither filling up the canal of the artery, nor adhering, except to the newly-cicatrized extremities of the artery.

c. A small whitish substance, of the consistence of jelly, projecting from the closed extremity of the artery, and being, in all probability, the remains of the external coagulum.

PLATE II.

Fig. 1.

Fig. 2.

PLATE II.

Fig 1. Represents a portion of the carotid artery of a horse six hours after it had been divided. The artery, its sheath, and the external coagulum are cut open. This particular section prevents the sheath from being seen, as it has not been separated, and, therefore, is not to be distinguished from the rest of the cellular membrane, every part of which around the artery is equally distended with blood; but the extent of the external coagulum, formed in the canal of the sheath, is here marked, and still more strongly in the preparation, by a difference of colour: this difference is most striking where the coagulum is applied to the divided extremity of the artery, to which it firmly adheres. This upper portion of the external coagulum appears to be coagulated lymph. Above, the base of the internal coagulum adheres to it. See Chap. I. Sect. II. Exp. XI.

a a a a. The cellular membrane, surrounding the artery, very much distended with coagulated blood.

b b b b. The outer lamina of the cellular membrane which surrounds the artery.

c. A portion of the carotid artery cut open.

d d. The external coagulum of blood.

e. The upper portion of the external coagulum, much whiter than the rest, and having the appearance of lymph.

f. The extremity of the artery adhering to the external coagulum.

g. The internal coagulum of blood, adhering only at its base, occupying but a small portion of the cavity of the artery, having a conical figure, and terminating opposite to the first collateral branch.

h. The first collateral branch.

i. The Parvagum.

Fig. 2. Represents a portion of the carotid artery of a horse sixty-six hours after it had been divided. The inner lamina of cellular membrane that surrounds the artery, or its sheath, is separated from the rest of the cellular membrane, and from the artery. It is much thickened by the distension of its cells with coagulated blood. On one side it has been separated from the artery to show the retraction of the latter within it, and the external coagulum occupying the canal formed by that retraction, and united to the truncated extremity of the artery: on the other side, not being separated, it conceals the extremity of the artery, and the external coagulum, and is intimately united to them. See Chap. I. Sect. II. Exp. XVII.

a a a a. The cellular membrane surrounding the artery turgid with coagulated blood.

b b. The sheath of the artery.

c. The sheath separated from the extremity of the artery and the external coagulum.

d. The sheath united to the external coagulum, and concealing the end of the artery.

e. The upper line points to the extremity of the artery, to the external coagulum in union with it, and just entering its cavity. The lower line marks where the external coagulum is lost in the surrounding mass of coagulated blood.

f. A portion of the carotid artery cut open, except at its lower extremity. It is very probable, that it contained a coagulum of blood, which extended to the first collateral branch; for a cylindrical and perfectly smooth coagulum, filling up the canal of the artery, but not adhering to its internal coat was found within the artery, separated to the distance of two inches above the external coagulum. It exactly corresponded in length to the space between the external coagulum, and the first collateral branch, and it seemed to have slipped from that, its original situation.

g. The first collateral branch.

PLATE III.

Fig. 1. Represents the left side of the neck of a dog seventy-two hours after Experiment XVIII. related in Chap. I. Sect. II. had been performed on it.

It shows an additional and very important circumstance; viz. the considerable quantity of coagulating lymph which is poured over the vessels, soon after they have been exposed, and by which a new covering is afforded them. The lymph has been separated from the surface of the artery to show it distinctly; but has been left entire over the jugular vein, and neighbouring parts.

a a a. Coagulated lymph, in which the vessels are enveloped.

b b b. Three large abscess-like cavities, which are lined with lymph, and contained large coagula of blood.

c c. The jugular vein covered to a considerable extent with coagulated lymph.

d. The space between the portions of the carotid artery covered with a layer of coagulated lymph, which extended over the sheath of the artery containing the external coagulum, and a little way over the extremity of the artery.

PLATE III.

Fig. 1.

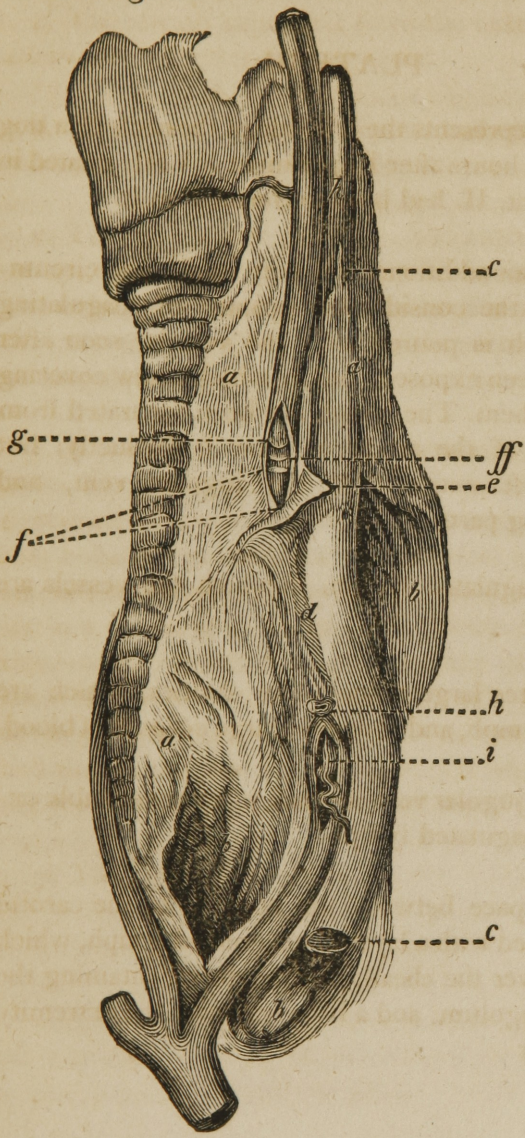
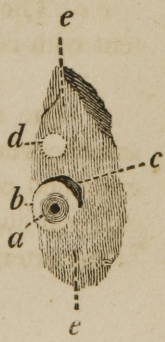


Fig. 2.



e. The portion of the layer of lymph, which extended over the sheath and extremity of the artery, turned back to show those parts more distinctly.

f. The lines drawn from *f* embrace the external coagulum, which is lodged in the sheath, and confined on each side by it. A small portion of the upper part of the coagulum has been removed to show the cut extremity of the artery.

ff. The cut extremity of the artery. The space between the line *ff* and the lowest line of *f* is the distance to which it has retracted within its sheath.

g. A portion of injection seen within the carotid artery, which has been cut open at its extremity. A small portion of the injection, which extended down to the extremity of the artery, has been picked away, that the termination of the artery may be distinctly seen.

The inferior part of fig. 1. represents the state of an artery seventy-two hours after the application of a ligature. See Chap. IV. Sect. I. Exp. IV.

h. The extremity of the carotid artery upon which a ligature has been applied.

i. A coagulum of blood filling up the canal of the artery, for the space of a quarter of an inch below the ligature, and then tapering for some distance. The convoluted appearance of the tapering extremity of this coagulum is owing to its having been compressed by injection thrown into the artery.

After a minute examination, I found that the coagulum adhered only to the cicatrized part of the artery.

Fig. II. represents a section of one of the carotid arteries of an ass, six days after it had been exposed by a very free incision, showing the artery completely coated with lymph.

a. The carotid artery.

b. A coat of lymph over the artery as thick as the artery itself.

c. Part of the cavity of the wound by which the artery had been exposed.

d. The Parvagum.

e e. The cellular membrane surrounding the carotid and parvagum filled with coagulated lymph.

PLATE IV.

Fig. 1.

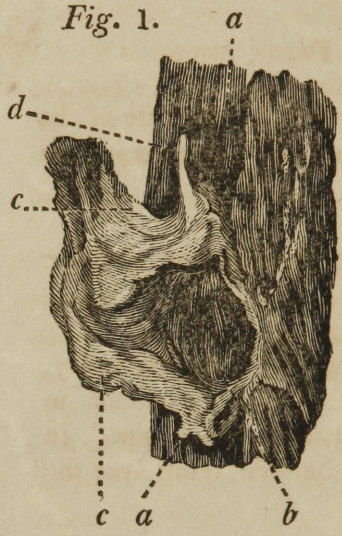


Fig. 3.

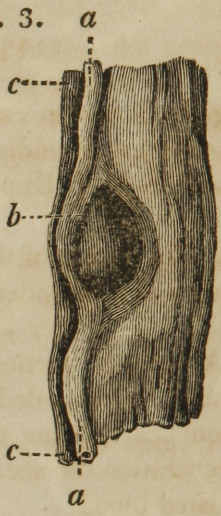


Fig. 2.

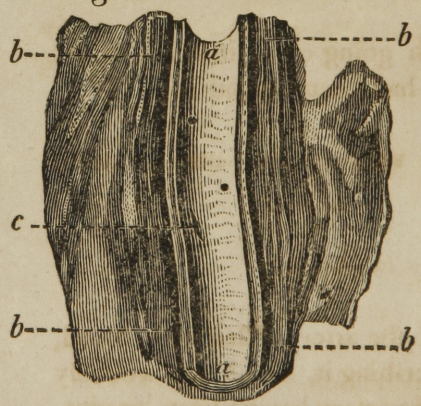


Fig. 4.

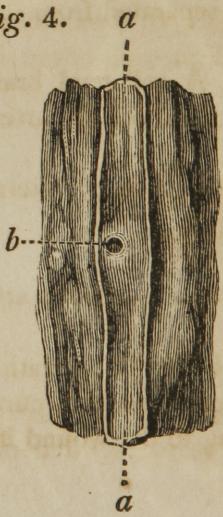


PLATE IV.

Fig. 1. Gives an external view of the state of the parts over the wounded carotid artery of a horse. See Chap. II. Sect. I. Exp. I.

a a. The sheath of the artery filled with blood above and below the wounded part.

b. A circular portion of the sheath of the artery, enclosing the wounded part, and more prominent in consequence of being more distended with blood. In the preparation the sheath can be seen, lying over the coagulated blood.

c c. Coagulated lymph, not from inflamed vessels, but separated from the blood which had been effused.

d. A collateral branch going off a little above the part at which the artery had been wounded.

Fig. 2. Is an internal view of the same wounded artery.

a a. The carotid artery cut open.

b b b b. The sheath of the artery filled with blood, and completely circumscribing it, which was probably owing to the wound in the artery having been longitu-

dinal, and very small, and, therefore, the hemorrhage by no means impetuous.

c. An internal view of the wound in the artery. It is a mere line, and its edges are in contact.

The two black dots on the artery represent the orifices of two collateral branches.

Fig. 3. Represents the state of the parts over a wound in the carotid artery of a dog eighteen days after it had been inflicted. See the same Chapter, Exp. VIII.

a a. The parvagum turned out of its course by a tumour.

b. A circumscribed tumour, formed by a portion of coagulated blood, placed immediately over the wounded part of the artery, and confined by a cyst which adhered to the artery, and to the surrounding parts.

c c. A portion of the carotid artery.

Fig. 4. Is an internal view of the same wounded artery.

a a. The artery cut open.

b. The wound which had been made transversely, is of a circular form, and is covered by a part of the

coagulated blood represented in fig. 3. *b*. There is a considerable thickening of the cellular membrane by the sides of the artery, opposite to the wounded part.

Of the numerous experiments that I made, this is the only one which presented an appearance of spurious aneurism.

PLATE V.

Fig. 1. Affords an external and lateral view of the state of the parts over and about a wound in the carotid artery of a horse, twenty-four hours after it had been inflicted. See Chap. II. Sect. I. Exp. II.

a a. Coagulated lymph forming the surface of the wound.

b. The center of the wound having a black appearance.

c c. The cellular membrane surrounding the artery and its sheath filled with blood.

d d. Coagulated lymph, originating from the side of the artery around the wound, extending up to its surface, and into the surrounding cellular membrane.

e. A collateral branch, given off a little above the wound in the artery.

f f. The wounded artery.

Fig. 2. Is an internal view of the same artery.

a. The artery cut open.

b b. The surrounding parts filled with coagulated blood.

PLATE V.

Fig. 1.

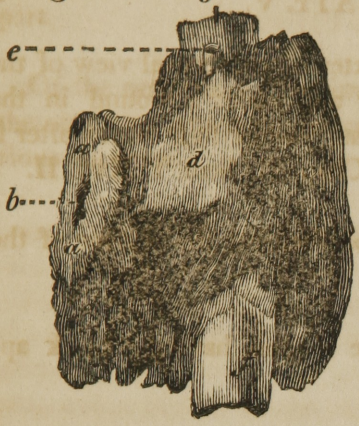


Fig. 3.

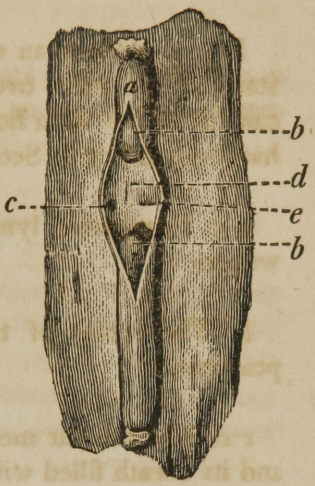


Fig. 2.

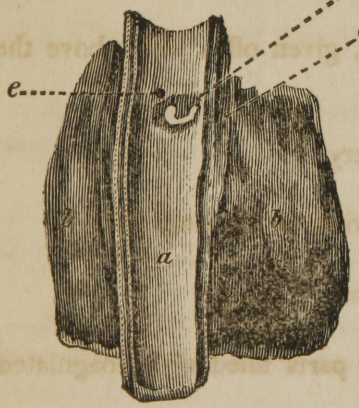
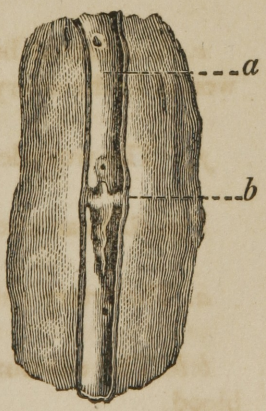


Fig. 4.



c. A thick stratum of coagulated lymph by the side of the artery, opposite to the wound. A similar effusion of lymph may be seen on the other side of the artery.

d. The wound in the artery completely filled up with lymph, but not so as to interfere in the least with the passage of the blood through the artery.

e. The mouth of a collateral branch.

Fig. 3. represents a portion of the carotid artery of a dog, nine days after it had been wounded longitudinally. The artery is cut open at its posterior part, and a portion of the injection, which had been thrown into it, picked away to give a clear view of the wounded part. See the same Chapter, Exp. VI.

a. The portion of the artery cut open, and cleared from the injection at its wounded part.

b b. The portions of the injection left.

c. A collateral branch, opposite to the wound in the artery.

d. The wound in the artery perfectly reunited, without obstructing the passage of the blood.

e. A very thin lamina of coagulated lymph adhering to the internal surface of the artery, opposite to the wound.

Fig. 4. Presents an internal view of a portion of the femoral artery of a dog, eleven days after a considerable transverse wound had been inflicted on it. See the same Chapter, Exp. VII.

a. The artery cut open, and the mouths of several collateral branches seen.

b. The part at which the artery had been wounded. At this part a thick stratum of lymph lines the internal surface of the artery, and from the center of which a long tapering coagulum hangs in the inferior portion of the artery; and immediately opposite to this, a small coagulum projects into the upper part of the canal of the artery. The cellular membrane opposite to the wound is thickened.

PLATE VI.

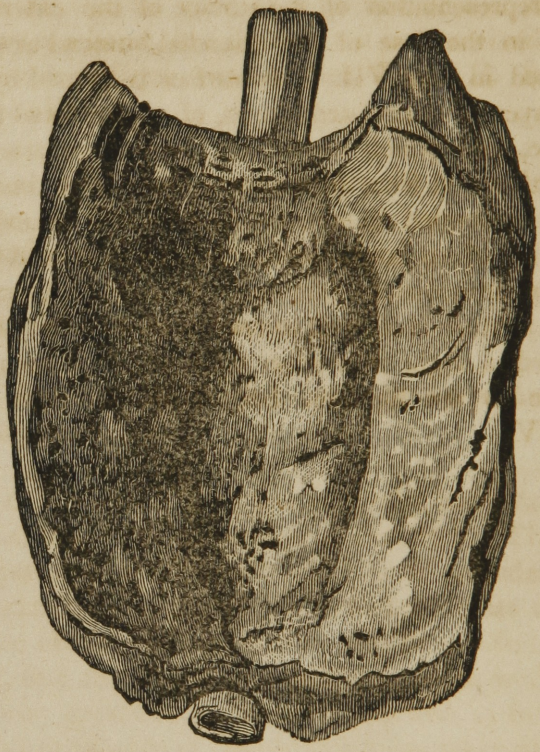


PLATE VI.

Is a representation of the surface of the external wound, in the case of the wounded humeral artery delineated in plate VII. This surface is formed by a thick layer of coagulated lymph, of a granulated appearance, and which completely covers the artery, and excludes it from the external wound. A similar surface is formed in every instance of a wounded artery, or of an artery which has been tied and the ligatures immediately removed. It is even formed when a ligature is allowed to remain on an artery, but afterwards a slight ulceration takes place through it, opposite to the ligature. See Chap. II. Sect. I. Exp. IV.

PLATE VII.

Is an internal view of a portion of the humeral artery of a horse, five days after it had received a considerable oblique wound. See Chap. II. Sect. I. Exp. IV.

a a. The cellular membrane, for a considerable space by the side of the artery, opposite to the wounded part, filled with coagulated lymph.

b b. The artery cut open.

c. A septum of lymph behind which a probe could readily be passed.

d d. A very thick portion of lymph inseparably attached to the internal surface of the artery. This was the part at which the artery had been wounded, but the extent and figure of the wound are quite effaced by the effusion of lymph. We may be satisfied, however, that the wound was considerable, as well from the very great hemorrhage that followed, as from the abundant effusion of lymph, which has taken place.

e. A thick and nearly oval portion of lymph adhering to the internal surface of the artery, and connected with the lymph *d d.*

PLATE VII.

PLATE VIII.

Fig. 1.

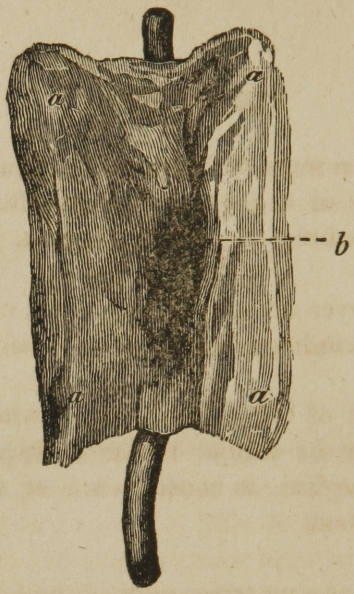


Fig. 2.

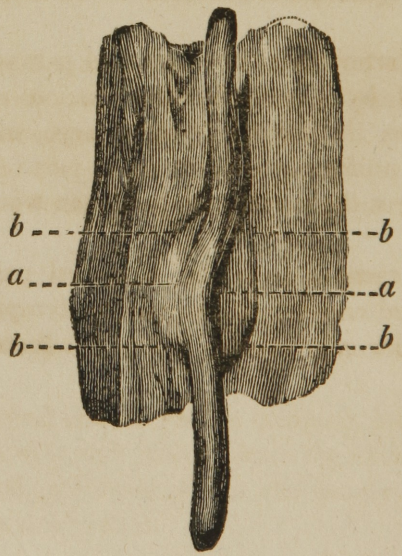


PLATE VIII.

Fig. 1. Represents the surface of a wound over the carotid artery of a dog, eight days after the artery had been punctured. See Chap. II. Sect. I. Exp. V.

a a a a. A layer of coagulated lymph, covering the artery, and excluding it from the external wound.

b. That part of the layer of lymph which lies immediately over the wound in the artery. It is dark *only at the surface*, in consequence of some intermixture of blood.

Fig. 2. Gives a posterior view of the same artery.

a a. The artery near the wounded part very much strengthened by a considerable effusion of lymph. Injection was thrown into this artery, and passed readily and uniformly though every part of it, without escaping at the part which had been wounded.

b b b b. A tumour over the wounded part of the artery, formed entirely by coagulating lymph, effused in the cellular membrane. It firmly adheres to the artery.

PLATE IX.

Represents the state of the femoral artery of a dog, twenty-two days after it had been wounded to the extent of half its circumference. See Chap. II. Sect. I. Exp. XI.

a. The superior portion of the femoral artery cut open at its extremity.

b. A coagulum of an irregular form, lying a little within, and projecting from the extremity of the artery. It appears turned a little to one side. In fact, its formation and position must have been interrupted and deranged by the repeated hemorrhages.

c. A small space between the side of the extremity of the artery, and the coagulum, from whence the frequent hemorrhages proceeded.

d. The inferior portion of the same artery cut open.

e. The extremity of this inferior portion of the artery closely contracted around a small coagulum of lymph, which adheres firmly to its internal surface.

f. A cylindrical coagulum of blood, attached to the coagulum of lymph which closes the extremity of the artery, and projecting within the canal of the artery, but not adhering to it.

PLATE IX.

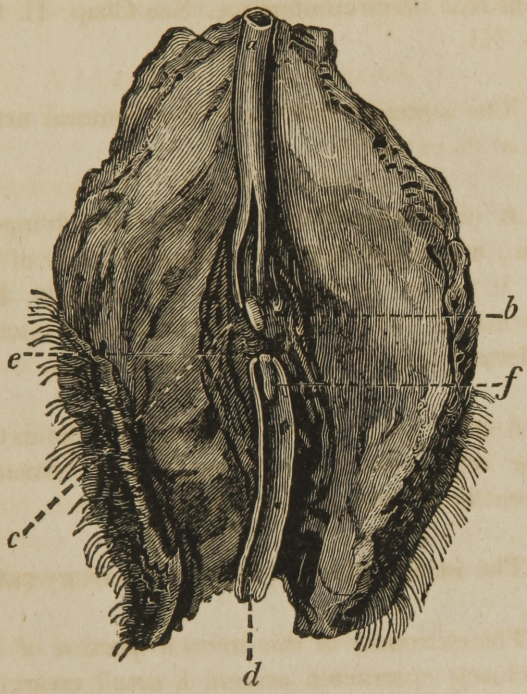


PLATE X.

Fig. 2.

Fig. 1.

PLATE X.

Fig. 1. Presents a view of the external wound over the femoral artery of a dog, twenty-five days after half the circumference of that artery had been cut through. See Chap. II. Sect. I. Exp. XII.

a. The surface of the bottom of the wound covered with lymph.

b. The surface formed by cutting away the integuments which hung over the wound, so as to prevent it from being distinctly seen. Previous to the removal of the integuments, the cavity of the wound was considerable.

c. A portion of lymph, projecting from the surface of the wound, opposite to the aperture which led to the artery.

d d. A border of lymph, enclosing and hanging over the aperture from which the hemorrhages proceeded.

e. The aperture partially represented. In the preparation it cannot be seen unless the border which surrounds it is raised up. It will admit a small probe to pass through it.

Fig. 2. Is a representation of the artery which belongs to fig. 1. cut open at its posterior part.

a a. The superior and inferior portions of the artery cut open posteriorly.

b. The extremity of the inferior portion, completely closed, and of a conical form.

c. A substance, connecting the two extremities of the artery, formed, no doubt, by an effusion of lymph into the cells of the sheath which was continued between them.

d. The extremity of the superior portion of the artery.

e. A coagulum of lymph, adhering to the sides, and posterior part of the artery where it was cut open, but not united to the anterior part of the artery.

f. The aperture through which the artery bled. It is situated over the coagulum *e*, between it and the anterior part of the artery.

g. A considerable longitudinal plica, extending a little beyond the first lateral branch. This was the only instance, in the whole course of my experiments, in which I had an opportunity of observing such a longitudinal fold in an artery after it had been injured.

PLATE XI.

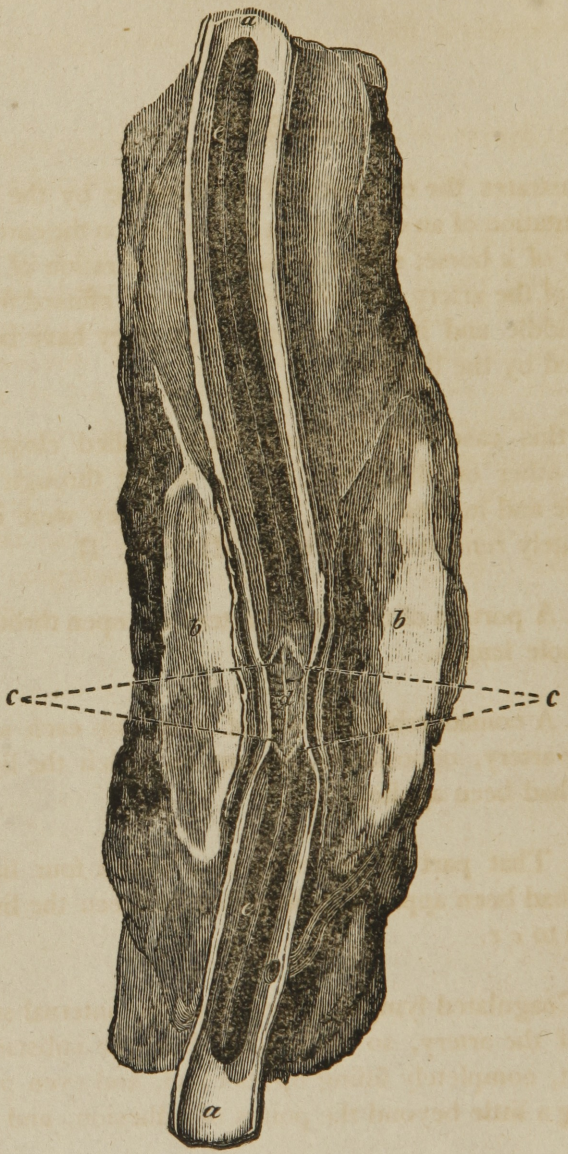


PLATE XI.

Illustrates the operation of the ligature by the representation of an experiment performed on the carotid artery of a horse; showing that the obliteration of the canal of the artery is produced by lymph, effused from its middle and internal coats where they have been divided by the ligature.

In this case four ligatures were applied close to each other on the artery, so as to cut through its middle and internal coats, after which they were immediately removed. See chap. III. Exp. II.

a a. A portion of the carotid artery cut open through its whole length.

b b. A considerable effusion of lymph on each side of the artery, opposite to the part on which the ligatures had been applied.

c c. That part of the artery over which four ligatures had been applied, is included between the lines drawn to *c c.*

d. Coagulated lymph, adhering to the internal surface of the artery, so as to form but one substance with it, completely filling up its canal, and even projecting a little beyond the points of adhesion, and in-

termixing, above and below, with a coagulum of blood.

Some transverse lines are seen on the lymph, marking where the ligatures had been applied.

e e. Two coagula of blood adhering to the lymph which obstructs the artery, but not to any part of the internal surface of the artery, the canal of which they completely fill. In viewing this plate we may, at first, be led to suppose, that the coagula of blood by no means fill the canal of the artery; but the deception is occasioned by the considerable separation of the edges of the artery from each other, in order to give a fair view of the parts within. In the lower portion the coagulum has extended even beyond a collateral branch.

PLATE XII.

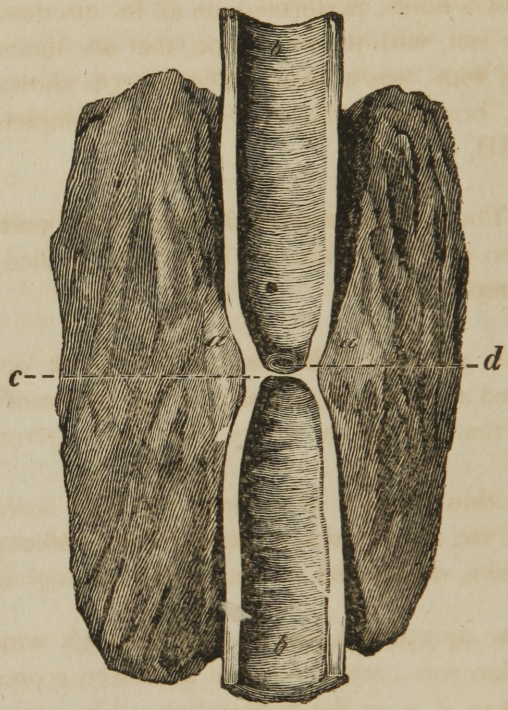


PLATE XII.

Represents the effect of an experiment on the carotid artery of a horse, performed, in all its circumstances, like the last, with the exception, that one ligature, instead of four, was applied. The effect is shown to be similar, but the obliteration is not so complete. See Chap. III. Exp. III.

a a. The cellular membrane around that part of the artery on which the ligature had been applied, filled with lymph.

b b. A portion of the carotid artery cut open. It contained a very small and slender coagulum of blood, only in that part of the artery above the septum.

c. A thin septum of lymph, standing across the canal of the artery, which considerably, although not completely, obstructed the circulation through it.

d. The aperture in the septum through which the circulation was carried on; but it is here represented larger than it is in the preparation. The parietes of the artery, opposite to the septum, appear indented, as if they had been affected with stricture.

PLATE XIII.

Represents the effect of an experiment, performed on the carotid artery of a horse, in the same manner as those delineated in plates XI. and XII. except that two ligatures were applied. The obstruction is complete. See chap. III. Exp. V.

a a. Thick strata of lymph by the side of the artery, and which completely covered it.

b b. A portion of the carotid artery cut open above and below the obstructed part. It contained in each part a large coagulum of blood, which has been removed to show the obstruction.

c. That part of the artery around which the ligatures had been applied is seen entire. Its canal, through the whole of this space, is completely filled up with lymph, which adheres firmly to its internal surface. Two dark lines, imperfectly surrounding the obstructed part of the artery, mark where the ligatures had been applied.

d. A portion of the lymph, which fills up the canal of the artery, projecting above the obstructed part.

e. The impervious termination of the artery below the obstructed part, being precisely the same as if a ligature had been applied, and allowed to separate by ulceration.

PLATE XIII.

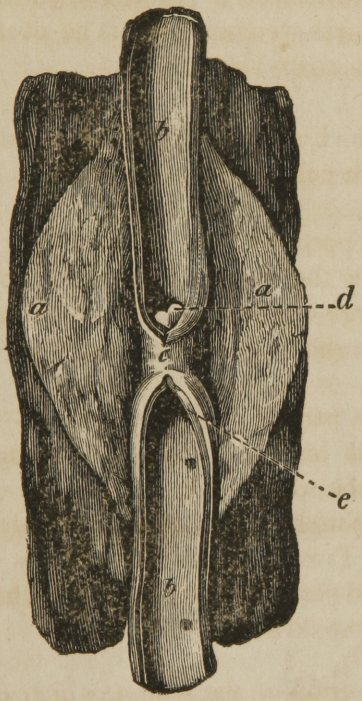


PLATE XIV.

Fig. 1.

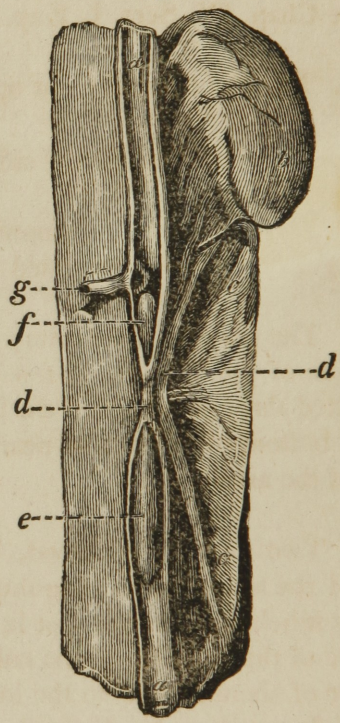


Fig. 2.

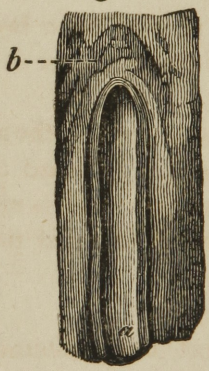


PLATE XIV.

Fig. 1. Is a side view of the carotid artery of a dog, twelve days after a single ligature had been applied on it. See Chap. IV. Sect. I. Exp. VIII.

a a. The carotid artery cut open.

b. A gland situated by the side of the carotid.

c c. The surface of the wound, formed by a layer of coagulated lymph, perforated by the ligature.

d d. The portion of the artery obliterated by the application of the ligature. A few fibres, which had not ulcerated through, detained the ligature, which is seen in the bottom of the wound near the obliterated portion of the artery.

e f. Two coagula of blood, next the obliterated part of the artery. The coagulum in the upper portion is much shorter than that in the lower, in consequence of the situation of the collateral branch *g;* but neither of them adhere to the internal surface of the artery. It may here be distinctly seen, that, in consequence of the contraction of the artery going on next the obliterated part, the conical form of the coagulum becomes reversed; for, at first, that part of the coagulum which lies nearest to the obliterated portion of the artery, is the base of the cone, but it becomes so

much compressed by the gradual contraction of the artery, as to be converted into the apex.

Fig. 2. Is a magnified view of a portion of the carotid artery of a dog, showing the cicatrization of its wounded surfaces, which were brought into contact by the ligature.

a. The artery cut open. The part which had been brought together by the ligature is completely united, but, as yet, has contracted very little. It contained a long conical coagulum, which has been removed, that the internal view of the united portion may be more complete. The sides of the artery, when smoothly and properly approximated, are united by lymph at a mere point.

b. The cellular membrane, a little beyond the united portion of the artery, considerably thickened with lymph.

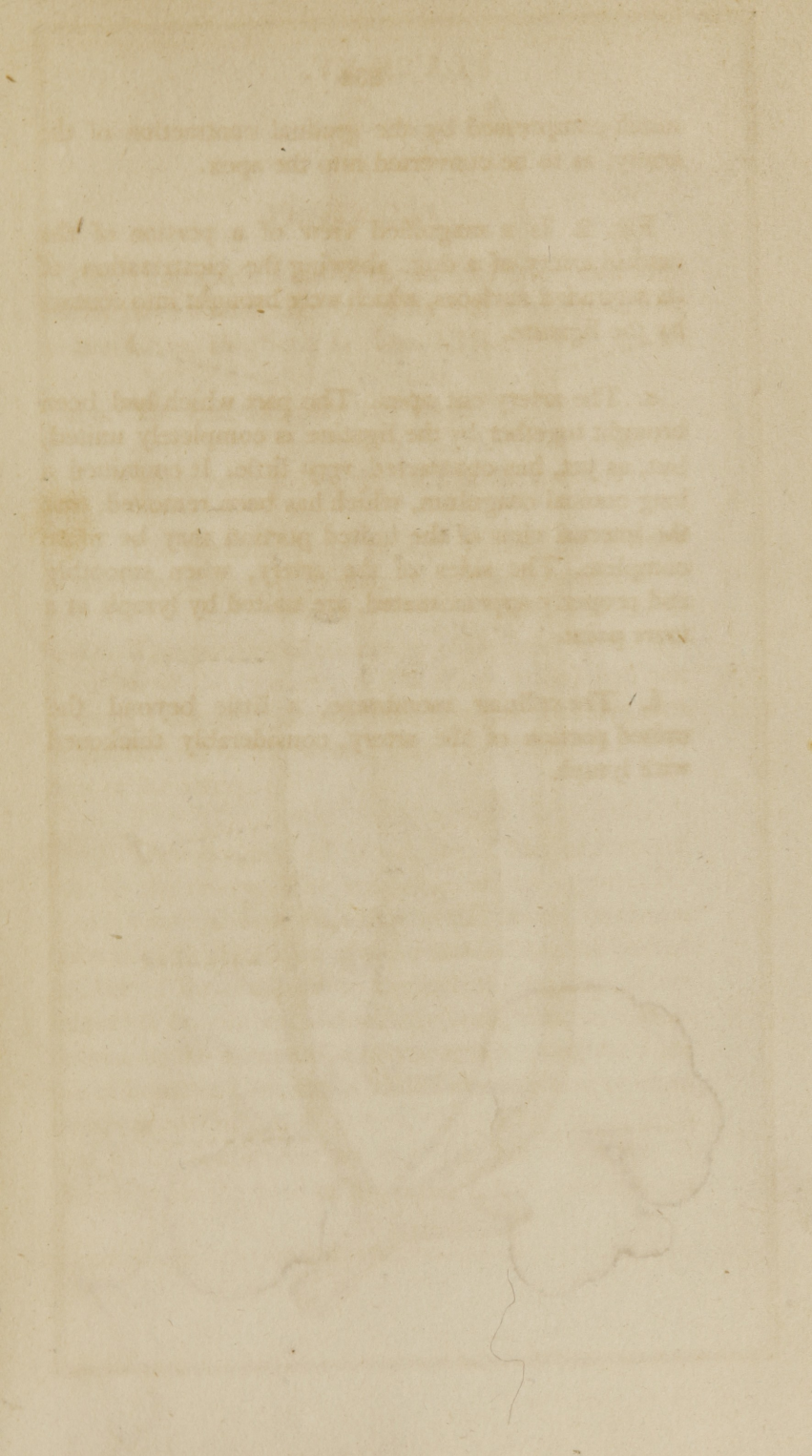


PLATE XV.

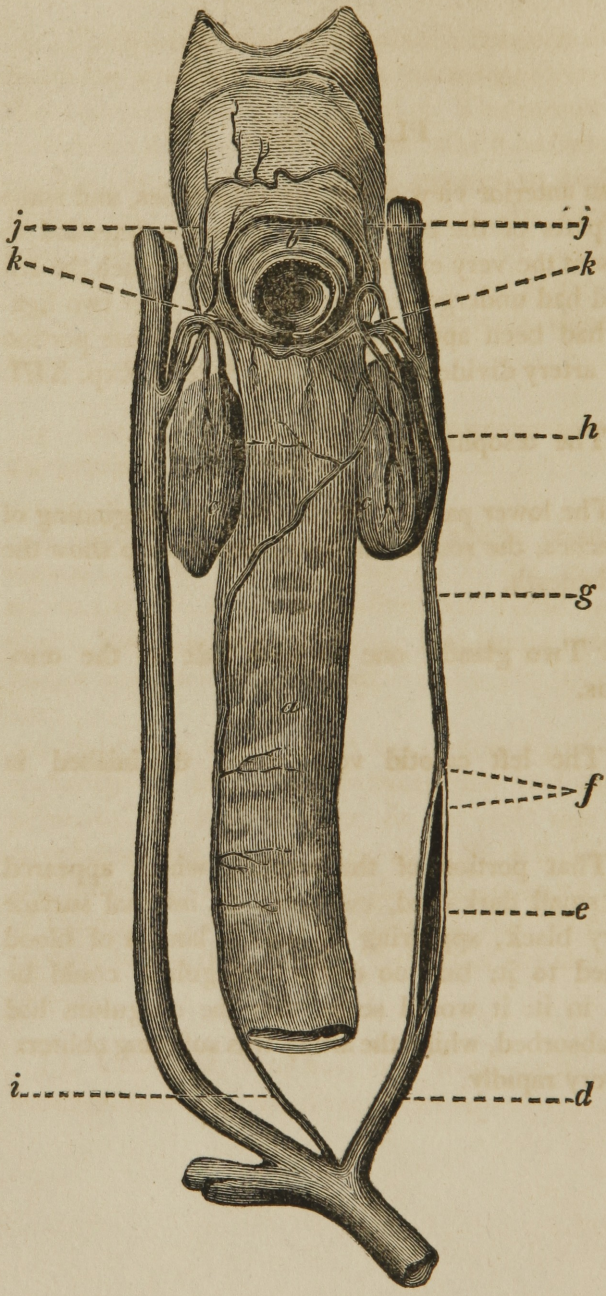


PLATE XV.

Is an anterior view of the carotid arteries, and some other parts of the neck of a dog; and is intended to represent the very extensive obliteration which the left carotid had undergone, forty-nine days after two ligatures had been applied, and the intermediate portion of the artery divided. See Ch. IV. Sect. I. Exp. XIII.

a. The œsophagus.

b. The lower part of the larynx, and beginning of the trachea; the rest having been removed to show the parts beneath.

c c. Two glands, one on each side of the œsophagus.

d. The left carotid very much diminished in size.

e. That portion of the carotid, which appeared like a small dark cord, cut open. Its internal surface is very black, appearing to have a lamina of blood attached to it; but no distinct coagulum could be found in it: it would seem, that the coagulum had been absorbed, whilst the artery was suffering obliteration very rapidly.

f. The portion of artery, included between the two lines, has a dense, firm, and white appearance—in short, it resembles a little tendon. The narrow part, just above the upper line, is that, which has been dissevered by the ligature, and appears to be lymph effused into the sheath of the artery, by means of which the two obliterated portions of artery are reunited. The superior portion is undergoing obliteration very rapidly, and it is extremely difficult to say exactly where it terminates.

g. The obliterated part of the superior portion of the carotid.

h. The point to which the complete obliteration extends. Above the line drawn to *h*, the artery terminates in a cone, and the obliteration would, without doubt, have continued up to the first lateral branch, if longer time had been allowed.

i. A branch, given off at the posterior part of the curvature of the aorta, between the two carotids, passes up, for some distance, on the right side of the œsophagus, then turns obliquely to the left side of it, and anastomoses freely with the first collateral branch of the upper portion of the carotid, and thereby remedies, in a certain degree, the loss of the obliterated carotid.

j j. Collateral branches, one from each carotid, anastomosing over the thyroid cartilage.

k k. Collateral branches, one from each carotid, anastomosing behind the trachea, between it and the œsophagus.

The right carotid is much enlarged.

THE END.

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