

III.

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 15 Plates. By J. F. D. JONES, M. D. Member of the Royal College of Surgeons of London. 8vo. pp. 237. London. 1805.

OUR curiosity, early attracted by the importance of the subjects announced in the title, has been amply gratified by the perusal of this interesting volume, which has left upon our minds very favourable impressions of the critical judgment of the author, as well as of his talent for experimental inquiry.

Few facts in physiology are more curious, or more interesting to the naturalist, than those which belong to the subject of animal reproduction: There are few of higher importance to the surgeon, for this knowledge points out to him, in many cases, at once the object and the limits of his art. The processes employed by nature in the reproduction and reunion of separated parts are the fairest subjects of experimental inquiry, and the labours of many ingenious men have accordingly been rewarded by the deriving of new and important facts. The observations and experiments of Duhamel, Haller, Troyes, and McDonald; of Murray, Huhn, and Hunter; of Cruickshanks and of Haughton, leave, indeed, little to desire in the departments which they have examined.

From the most perfect restoration of a lost or amputated part, to the cicatrization of the simplest wound, we observe a uniformity in the attempts of nature at reproduction, or a series of analogous events, which expound to us the processes of nature in the reproduction and reunion of the bones, and of most of the soft parts of animals. The process employed by nature in suppressing the hemorrhage from divided arteries, though perhaps of all the most important to be fully understood, has not been so perfectly explained. Experiments and observations, indeed, have not been more neglected here; badly imagined, however, and limited in their direction, by the influence of some hypothesis to be confirmed or refuted, they leave us still uncertain of the truth. Some steps of the process have been seen or affirmed, while others, equally important and efficient, have been over-

looked or denied. Limited observation, and the inclination to simplify the mechanism of nature, have led to theories founded on some one or other of the steps of the entire process; and hemorrhage has been supposed to be naturally stopped by an obstructing clot of blood, by the contraction and crispation of the divided artery itself, or by the tumefaction or injection of the surrounding cellular substance. The limited theories of Petit, of Morand, and of Pouteau, gave rise to other subordinate hypotheses not more satisfactory. Distrusting, then, these results of partial observation and of hasty conjecture; to arrive at the truth, it was necessary again to consult nature herself, and by a series of observations and experiments, carried on through every stage of the process, from the first effusion of blood to the natural suppression of the hemorrhage, and complete cicatrization of the wounded artery, to mark the various changes which take place, and the order in which they succeed: a task which has been undertaken and executed, with equal zeal, ability, and success, by Dr Jones.

The experiments are numerous, but not redundant; they are well imagined, skilfully executed, and, to all appearance, faithfully related. The results are also exhibited in 15 neat engravings. The experiments are compared with, and his observations are afterwards illustrated and confirmed by those of other eminent physiologists and surgeons: For the error of his predecessors seems to have been chiefly that of seizing exclusively one step of the process of nature which they really did observe, and of hastily concluding that they had nothing farther to look for. So far, indeed, as they did observe, their observation was correct and accurate; but this being limited to some particular period of the process, they differently saw the corresponding steps of a series of changes, which really constitute the process of nature in suppressing the hemorrhage from divided or wounded arteries.

Dr Jones having examined and freely exposed the defects of Petit, Morand, Sharp, Pouteau, Gooch, Kirkland, and J. Bell, proceeds in the relation of a series of experiments on the arteries of horses and dogs, undertaken with the view of ascertaining the process employed by nature in the suppression of hemorrhage from *divided* arteries, and the order of the events which constitute it. In these experiments the larger arteries were completely divided; the suppression of the hemorrhage was left to nature, and the condition of the divided vessel was, in the different cases, ascertained by careful examination, at different periods, after the first cessation of the hemorrhage. Though we must refer to the original for a full detail of those experiments, we shall here quote the following as examples.

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 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 tumour 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 tinged 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 lamina of the sheath. The internal coagulum was an inch and a half long, corresponding to the distance between the external coagulum 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 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.'

Not one, then, but a variety of circumstances conspires in the natural suppression of the hemorrhage from *divided* arteries. The divided artery retracts and contracts; the force of the circulation, after the first impetuous flow of blood, is gradually weakened and reduced; the blood is effused into the cellular substance, and the sheath within which the divided artery had retracted; the effused blood is here entangled, and the foundation laid for the formation of a coagulum, which fills the sheath and cellular membrane, and eventually closes up the mouth of the artery;

and this, which is termed the external coagulum, is the first complete barrier to the effusion of blood. "This coagulum, viewed externally, appears like a continuation of the artery, but, on cutting up the artery, its termination can be distinctly seen with the coagulum completely shutting up its mouth, and enclosed in its sheath."

The next step in the process is the formation of the *internal coagulum*, the clot within the artery, a slender conical clot which lies loose in the arterial canal, and connected with the artery only by its base, which, by its circumference, is slightly attached to the divided extremity of the vessel. The formation of this internal coagulum, however, appears to be merely a contingent event in the process, and depends on the cessation of the circulation in that part of the artery which lies between the first collateral branch and the divided extremity, after that extremity has been closed, and the hemorrhage stopped by the external coagulum. The figure and size of the internal coagulum vary according to the remoteness of the first collateral branch, and where this goes off very near to the divided extremity of the artery, the internal clot is often not to be found. "The *internal coagulum* 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."

Soon after, there is observed, between the external and internal coagula, a layer of coagulable lymph, poured out by the inflamed vessels of the cut extremity of the artery, to the internal coat of which this coagulum of lymph is firmly united. And now, by the gradual contraction of the artery, and by the effusion of lymph, these parts become intimately blended together; the canal of the artery is obliterated, and its extremity lost in the surrounding parts. Thus, the *temporary* suppression of the hemorrhage is accomplished by the retraction and contraction of the artery, and by the formation of the coagula, or clots of blood; permanent security is afterwards obtained by the effusion, consolidation, and organization of coagulable lymph. The artery, however, gradually undergoes other changes: "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 entirely 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,

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."

Such is the outline of the process employed by nature for the suppression of hemorrhage from *divided* arteries, as more fully deduced by our author from his own experiments and observations, and which he very happily illustrates and confirms by a judicious exposition and criticism of some of the observations of Pouteau, Kirkland, Morand, Gooch, Haller, and others.

Let us conclude, then, with Dr Jones, that "we can no longer consider the suppression of hemorrhage as a simple, a mere mechanical effect, but as a process prepared by the concurrent and successive operations of many causes: These may be briefly 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 coagulable lymph within its canal, between its tunics, and in the cellular substance surrounding it."

We now pass to the 2d chapter of this treatise:—"On the means which nature employs for suppressing hemorrhage from *punctured* or *partially divided* arteries; and on the process of reparation which takes place in those arteries."

The common consequence of a punctured artery, in man at least, is the formation of aneurism; and the experiments of this chapter were originally instituted with the view of ascertaining the manner in which aneurism is produced, and with little hope of witnessing the complete and perfect reunion of a partially wounded artery. But Dr Jones found it very difficult to produce aneurisms in the arteries of horses and dogs; on the contrary, he discovered that, when the artery was simply punctured, the wound often cicatrized by a process of reparation, its canal continuing pervious, and its functions entire; or, when a larger portion of the circumference of the artery was wounded, that either the canal of the artery became obstructed, or that a complete division took place by laceration or ulceration.

We shall take the 6th of this series of experiments as an example of the cicatrization of a punctured artery.

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."

But if these animals had been longer preserved, if they had fully recovered their blood and health, if they had been allowed to return to their wonted freedom and exercise, might not these cicatrized arteries have dilated into aneurisms ? However this may be, the process of cicatrization, as deduced from these experiments, appears to be this :—The sheath becomes injected with blood ; the relative position of the puncture in the artery and in the sheath is altered, so that they no longer oppose each other ; a layer of coagulated blood is confined by the sheath over the puncture in the artery, and forms the *temporary* barrier to farther hemorrhage. Lymph is now effused under the coagulum of blood, and the process of reparation is completed in the usual way, till permanent security is obtained.

Though it appears, from Dr Jones's experiments, that the punctured arteries of brute animals may thus be cicatrized, and their functions preserved entire, we are not to flatter ourselves with equal success in the surgery of wounded arteries in man. Although there is such an appearance of cicatrix in a case quoted from Petit, we perfectly agree with Dr Jones, that in the treatment of a wounded artery, " 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 between the ligatures."

Chapter 3d :—" 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 experiments contained under this head are novel, and highly interesting. In these, after exposing the arteries, ligatures were passed round them, and tied in the usual way, but, immediately afterwards, loosened and withdrawn ; the freedom of circulation was instantly restored, and the blood passed through the artery as before the application of the ligature. Yet, very shortly after, the artery became obstructed, and was eventually cicatrized

cicatrized for some way above and below where the ligature had operated, and that as effectually as if the ligature had been suffered to remain. The process by which this is brought about seems to consist of the following parts : The internal and middle coats of the artery are torn or divided by the ligature, an observation first made by Desfaulx, and confirmed by Mr Thomson and by Dr Jones ; the divided coats inflame ; coagulable lymph is poured out so abundantly as to obstruct the arterial canal ; above and below this obstructing coagulated lymph there are formed internal clots, or coagula of blood, as far as the first collateral branches, which complete the obstruction, and at length all this portion of the artery becomes cicatrized, with the circumstances more fully exposed by our author in the next chapter, " On the process of adhesion, and the changes which an artery finally undergoes, in consequence of the application of the ligature."

In the experiments undertaken with a view to the investigation of this process, the ligatures were applied in the usual manner, and allowed to remain, the artery being, in some, divided between two ligatures, and allowed to retract, and, in other cases, left undivided.

From the whole of Dr Jones's experiments, it appears that the effects of tying an artery properly are,

1st, To cut through the internal and middle coats of the artery, and to bring the wounded surfaces into perfect opposition.

2^d, To occasion a determination of blood on the collateral branches.

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

4th, 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.

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

6th, 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.

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

A knowledge of the changes which an artery undergoes, in consequence of the application of the ligature, explains to us, at the same time, its occasional failure, and instructs us how to avoid some of the causes of secondary hemorrhage; those, at least, which depend on the improper form and application of the ligature. And, with some very pertinent remarks on this subject, Dr Jones brings his treatise to a close.

It is proved by some experiments of Dr Jones, that, to produce those changes in the artery which terminate in the adhesion of its coats and obliteration of its canal, which it is our object to attain by the proper application of the ligature, it is necessary that the internal and middle coats of the artery be completely divided by the ligature; and hence that form and mode of application, which are best calculated to produce this requisite division of the internal coats, must be preferred. Large flat ligatures are therefore improper; round ligatures, which are small and sufficiently firm, are preferable; they should be perfectly regular. No part ought to be included in the ligature but the artery. Care should be taken to tie the ligature with sufficient force, and always as nearly as possible in the direction perpendicular to the axis of the artery. The artery itself should, in every case, be as little as possible detached from the neighbouring parts; and, if experience has discovered any advantage in the mode of tying and dividing the artery between two ligatures, Dr Jones is disposed to think that this advantage consists in the artery being tied close to the part at which its connexion with the surrounding cellular membrane is complete; whereas, when a single ligature is used, a considerable portion of the artery is detached, and the ligature, perhaps, applied in the centre; or, if applied at the upper end, still there remains a considerable portion of detached artery below it.

From the foregoing analysis, our readers will be enabled to anticipate the general merits of this excellent treatise. To us it appears a work of uncommon merit, and we doubt not our judgment will be confirmed by every one who, after an attentive perusal, considers the unusual labour bestowed upon it, the great number of facts contained in it, the excellence of the plan by which all those facts are arranged, the precise and accurate development of the most important processes, of which very inadequate and confused notions had been formerly entertained, and the industry and fidelity with which they have been illustrated by the scattered facts relating to these collected from the writings of others.