RESEARCHES

INTO

THE CONNECTION EXISTING BETWEEN AN UNNATURAL
DEGREE OF COMPRESSION OF THE BLOOD
CONTAINED IN THE RENAL VESSELS,

AND

THE PRESENCE OF CERTAIN ABNORMAL MATTERS IN
THE URINE.

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HAVING undertaken some experiments with the view of determining the precise cause of the appearance of albumen in the urine, I found that not only liquid albumen and blood, but coagulating lymph or fibrine also escaped into the urinary passages as the consequence of an obstruction to the return of blood through the renal vein. As the unnatural compression of the blood in the renal vessels, thus artificially produced, gave rise to phenomena identical with those constituting the primary effects of inflammation, and as the kidney seemed to present greater facilities for an experimental investigation of that important subject than any other organ of the body, I was induced to

extend my observations, and to attempt certain modifications of the experiment. The facts thus obtained will, I think, enable us to explain, with more precision than has hitherto been attempted, the true reason of the variable nature of the effusion in different instances: and as this involves physiological and pathological points of some importance, the question may not be deemed unworthy of the consideration of the Society.

As a full description of each experiment must necessarily involve much repetition, and might, therefore, tend to weary and distract the attention, I shall in this place content myself with relating those general results which bear directly on the main object of this communication: leaving the particulars of each experiment to be more minutely described in the appendix to these remarks. With the exception of the first, all these experiments were performed on the kidneys of rabbits. The animals employed varied much in age, size, and condition; and as the strength of the system exerted a very material influence in modifying the nature of the effusion, each experiment must be considered by itself, in order to arrive at a strictly accurate conclusion.

My reasons for selecting the kidney were the following:—

This organ can be readily and quickly exposed in the lower animals, and its artery, vein, and duct, (which constitute almost the sole bonds of union between it and the rest of the body,) may be sepa-

ately secured by ligature: so that we not only have the circulation through the gland entirely under our command, but are, at the same time, enabled to isolate and confine the secretion, and thus prevent the possibility of error in examining the composition of the latter. Moreover, the recent discoveries of my friend, Mr. Bowman, by clearing away the mystery which had previously surrounded the Malpighian bodies, have made us well acquainted with the minute anatomy of the kidney, and have thereby enabled us more clearly to understand the mechanism of the process.

Having obtained all that I expected from obstructing the return of blood through the renal vein, I was anxious to ascertain the effect of directing, with different degrees of rapidity, an increased flow of blood to the vessels of an organ previously healthy: the passage of this blood being unimpeded by any artificial obstacle, and the organ itself being untouched. After some unsatisfactory trials, I at length obtained results precisely similar to those met with in the former series after venous obstruction.

Although the same general effects were produced in all the experiments, it will be more advantageous to consider them as arranged under two divisions.

The first, containing twenty experiments, in all of which some artificial impediment obstructed the flow of blood through the vein.

The second, comprising fourteen experiments, in

which an increased determination of blood was directed to one or both kidneys, without any artificial obstacle being opposed to its free return.

After the experiments on the kidneys were performed, it occurred to me, that the observation of the effects of venous obstruction in the vessels of a frog's foot might serve to illustrate the action of the same cause in the former cases.

Accordingly, the hinder extremity of a frog was so included within two ligatures that the artery and bone were the only parts left free. There was some slight oozing of serous fluid from the wound in the ham, and the limb below the ligature speedily became red and swollen. On looking at the vessels in the web with a moderate magnifying power, the veins were seen to be much enlarged, and, as it were, prolonged into the capillaries in consequence of the accumulation of blood in, and distension of, the latter.

At first sight, the blood appeared to have lost all motion; but on examining more attentively, some small arteries were observed in the act of pouring in fresh blood; the impulse of which propelled onwards the column in the veins at each contraction of the heart. During the cessation of that action a retrograde movement occurred: the two alternate actions causing an oscillation of the contained blood.

At the end of half an hour the globules had begun to cohere, and formed by their union irregular masses and cylindrical columns, which

moved to and fro synchronously with the contraction and relaxation of the ventricle; the former motion being evidently produced by the momentum of the arterial blood, the latter resulting from the resiliency of the elastic tissues.

At the end of seven hours the blood was completely stagnant in all the vessels.

At some points slight extravasation had apparently taken place, for the red outline of the vessels was irregular and ragged. In other places the red line marking their breadth was uniform and even; but a white line of opacity (not unlike that caused in transparent tissues by the effusion of lymph) was situated externally to it.

Various stimulants were then applied to the web without producing any distinct effect either on the vessels or on the blood which they contained. The limb never recovered its vitality, and subsequently underwent the various changes of mortification.

As these effects were such as might have been expected from previous reasoning, and as they were precisely analogous to those which I presumed to occur in the minute vessels of the kidney during the existence of an obstruction to the circulation of the blood through them, I did not think it necessary to repeat the observation.

CLASS I.—*Illustrating the effects of venous obstruction.*

A.—The ligature around the renal vein being tightly applied, and no hæmorrhage occurring from any of its branches.

No. of Experiment.	Interval between the application of ligature and death of the animal.	Composition of the urine as regards the presence in it of albumen, lymph or blood.
1	10 minutes.	Slightly albuminous.
2	30 minutes.	Ditto. ditto.
3	30 minutes.	No urine in bladder; ureter not examined.
4	10 minutes.	Highly albuminous.
5	6 minutes.	Very highly albuminous, and some slight appearance of fibrine.
6	3½ minutes.	Bloody.
7	1 hour.	Ditto.

These experiments alone suffice to show that the same kind of effusion does not necessarily and constantly result from the existence of the same degree of obstruction. It will be evident that this latter constitutes but one of the conditions required to cause the exudation of the more viscid portion of the blood through the coats of its containing vessels. A certain amount of impulse of the arterial blood must always co-exist and co-operate with the obstruction, before that species of effusion can take place. The activity of this force will of course be proportioned to the rapidity and vigour of the ventricular contractions; and it is to the varied power of the heart's action, at the moment of applying the ligature, that I ascribe the different results met with in the above experiments. I have throughout invariably observed that the effects of an intense degree of compression were chiefly to be expected in

those instances where the animal seemed to recover most speedily from the shock of the operation.

B.—The obstruction of the renal vein being either incomplete or gradually effected.

In 6 cases some venous hæmorrhage occurred from accidental or intentional laceration of the vein or its branches.

In 2, the coats of the vessel were raised by a forceps, and a ligature so applied as to include only half the vein; leaving it at the moment pervious, though of diminished calibre.

In 4, a thread was passed around the vein, and so tied as to enclose the latter within a loose loop; the vessel itself not being compressed by the ligature.

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The results will be most readily understood by a glance at the subjoined Table :

No. of each experiment as related in the Appendix.	Interval between the application of obstruction and death of the animal.	Composition of urine.
1	1 hour.	Slightly albuminous.
2	30 minutes.	Highly albuminous.
3	7 minutes.	Slightly albuminous.
4	1 hour.	A mass of lymph in the bladder.
5	1 hour.	Blood and fibrine.
6	1 hour.	Lymph and blood.
7	40 minutes.	Bloody.
8	4½ days.	Urine muddy and faintly albuminous.
9	18 hours.	Bloody.
10	1 hour.	Bloody.
11	24 hours. (?)	Moderately albuminous.
12	2½ days.	Reddened by blood, and highly albuminous.

The lymph found in the bladder, in one of these experiments (No. 4), was beautifully clear and pellucid. It was semi-fluid when first examined, but coagulated more firmly on exposure to the air.

I am not aware that any other instance is recorded of the effusion of coagulating lymph, as the consequence of simple compression of the blood from venous obstruction. The quantity was so considerable, in this case, and the manifestation of its peculiar properties so decided, that there was not the least room for doubt. The physical condition of the blood in the vessels of this kidney must have been that of a fluid subjected to a continued moderate pressure: for, in consequence of a slight laceration of the vein, the blood could not be compressed beyond a certain degree, as it would then tend to ooze through the lateral opening. I have not succeeded in obtaining so much lymph in any subsequent experiment. It must ever be a very difficult point so to adjust the obstruction to the amount of impulse of the arterial blood as to maintain the requisite degree of compression, and no more, for a sufficient length of time. The two succeeding experiments confirm the accuracy of the explanation just given: for in them the vein, being first tied tightly, was then punctured on the renal side of the ligature, so that a small jet of blood escaped. The organ being returned while in this condition, and the urine examined, at the end of an hour, both fibrinous and bloody coagula were found suspended in it. I think it not improbable that the blood, in these instances, escaped during the short interval

that elapsed between the application of the ligature, and the puncture of the vein. For it will be remembered that, in a former case, blood was found in the urine at the end of three minutes and a half after the obstruction took place.

Three of the above experiments (viz., the 8th, 11th, and 12th,) are related, not only for the illustration they afford, of the general principle here advocated, but from their tending to throw light upon the changes which these engorged organs would subsequently undergo. The circumstance of blood and albumen being present in the urine at so late a period as the third or fourth day after the operation, may be partially explained by the slow progress of bloody or fibrinous coagula along the ureter. At the same time, I think it is possible that some albumen may have been derived from the other kidney, in consequence of the increased determination to that organ. I cannot help thinking that the morbid appearances which these three engorged kidneys presented, viz., the formation of an exterior membrane or cyst, the appearance of white spots on the external surface of the organ, as in Experiment 12, and the more extensive disintegration met with in Experiment 8, were but the first of a series of changes which would finally have terminated in the softening down of the whole organ, and its conversion into a puriform mass. And it seems by no means improbable that when abscess of the kidney follows acute nephritis in the human subject, the formation of a bag of pus (as met with in *post mortem* examinations) takes

place in a similar manner, and is preceded by similar changes. An extended investigation of the changes which kidneys thus treated would finally undergo could not fail to throw important light on some of the secondary effects of inflammation.

I shall now pass on to the second class of experiments, or those intended to illustrate the effects of an increased determination of blood to the vessels of a part previously healthy.

It occurred to me, that if an increased flow of blood could be suddenly directed through any particular artery, the contractility of the smaller vessels would resist the rapid dilatation necessary for the free passage of the augmented quantity of fluid, and thus give rise to some obstruction. If any obstruction did take place, then both the conditions required to produce undue compression of the blood would co-exist, and some of its effects should be perceptible in the urine.

CLASS II.

A.—I first attempted to accomplish this end in the case of the renal artery by removing one kidney, thinking that the physiological determination to the other might suffice. I repeated the experiment five times, chiefly in young and weak animals. The only constant result observed was a progressive increase in the weight of the remaining kidney. In one instance there were some slight traces of albumen in the urine.

B.—I then, in two small weak animals, tied the

abdominal aorta below the origin of the renal arteries. In one instance the urine was slightly albuminous.

C.—As I did not by these measures, used singly, obtain very satisfactory results, I then wished to ascertain whether the simultaneous performance of both operations *in animals of greater strength*, would not, by the conjoint influence of the physical and physiological determination of blood to the remaining kidney, induce the presence of albuminous matters in its secretion. I performed seven experiments. The three first did not succeed; but a glance at the particulars of each, as given in the appendix, will, I think, suggest a satisfactory explanation of their failure. And any uncertainty which these negative results may have created as to the truth of the principle sought to be established in this part of the memoir, must be in a great measure removed by a careful perusal of the four last experiments. Thus in

The animal living		
Exp. 4.	18 hours.	The urine contained blood, and the liquid portion albumen.
5.	about 2 days.	It was highly albuminous.
6.	3½ hours.	A coagulum of blood, another of fibrine, and was highly albuminous.
7.	2 hours.	Blood and albumen.

In removing the left kidney, care was taken to

secure the ureter as well as the blood-vessels. That these albuminous matters were derived from the right kidney, is proved beyond a doubt by the existence of ecchymoses in its substance and on its surface in two instances, (Exp. 4th and 7th,) by the increase of its weight, as seen in Exp. 6 and 7, and by the fact of the morbid products being detected in the right ureter in Exp. 6.

By selecting strong full-blooded animals, the repetition of this experiment would doubtless yield results precisely similar to those just detailed. I think the experiments related in the first division of this class, though yielding but negative evidence in support of the main point of this inquiry, are not altogether undeserving of consideration, and may be advantageously contrasted with the four last of the third division. For we learn from the former that a gradually increased quantity of blood may be directed to the vessels of a part without occasioning any material obstruction and compression of that fluid. While the concluding experiments show clearly that if the quantity determined to any particular set of vessels be considerably and *suddenly* increased, then some of the ordinary effects of undue compression of the blood will be produced.

Having now mentioned concisely the general results obtained, I may be allowed to allude again for a moment to those two conditions by which the compression of the blood in its vessels is produced and regulated.

This compression is altogether dependent upon

the co-existence and co-operation of two essential causes, each of which will, in different individuals, vary much in its amount of activity or degree of completeness.

The momentum of the arterial blood arising from the contractions of the ventricle constitutes the active force from the operation of which the compression takes place. But as a counter resistance is required before an intense degree of the latter state can occur, it is only when some extraordinary obstruction to the free passage of the blood *through the smaller vessels* exists that the effects of an undue compression of that fluid are perceptible.

It follows, therefore, that the momentum being equal in a number of cases, the intensity of the compression of the blood will be proportioned to the completeness of the obstruction: and, on the other hand, the impediment or obstruction being equally complete, the degree of compression will then be commensurate with the amount of the momentum.

The whole of the preceding experiments, if carefully considered, will, I think, support this statement.

They also prove—

1. That simple compression of the blood in its smaller vessels will, in a direct ratio to the degree of intensity of that compression, cause the exudation of an albuminous fluid, of coagulating lymph, or the extravasation of blood. Its immediate effects, therefore, precisely resemble those of inflammation: and

as it is well ascertained that both the essential causes of undue compression (viz., an obstruction or impediment to the flow of blood through the vessels of the inflamed part, and excessive action of the heart,) co-exist in that disease, it seems but reasonable to infer that the primary effects of inflammation, being identical with those of undue compression of the blood, are the mere consequences of that physical cause.

2. That there is no relation between the composition of the effused matters and the extent of the dilatation of the coats of the vessels, as measured by the quantity of blood they contain. To establish this point more clearly, I subjoin a short Table, exhibiting the relative weights of the healthy and engorged organs, and the nature of the effusion.

Order of the Experiments in the Appendix.	Weight of healthy kidney.	Weight of engorged kidney.	Relative Weights.	Condition of the Urine.
Class 1.	grs.	grs.		
A. Exp. 1st.	20	40	1-2.	Faintly albuminous.
— 4th.	35	70	1-2.	Highly albuminous.
— 5th.	25	50	1-2.	Highly albuminous.
— 6th.	60	90	1-1.50	Bloody.
— 7th.	98	175	1-1.78	Bloody.
B. — 1st.	40	84	1-2.10	Slightly albuminous.
— 2nd.	50	150	1-3.	Highly albuminous.
— 4th.	100	130	1-1.30	A mass of lymph.
— 5th.	50	90	1-1.80	Bloody; with a fibrinous coagulum.
— 7th.	35	68	1-1.94	Bloody.
— 9th.	64	182	1-2.84	Bloody.
— 10th.	90	170	1-1.88	Bloody.

In conclusion, I may again repeat my opinion, that the process of the effusion of albumen and

lymph through the coats of the vessels of the living body is dependent on, and regulated by the degree of the compression of the blood contained within those vessels.

My chief object in undertaking this investigation was to endeavour to extend the application of ordinary physical laws to the explanation of some of the morbid and healthy phenomena of the animal body : for it seemed to me that if a few simple general principles could be established, we might then hope to understand more clearly the true nature of disease, and perhaps ultimately be enabled to treat it with greater success.

EXPERIMENTS ON THE KIDNEY.*

CLASS I.—*Illustrating the Effects of Venous Obstruction.*

A.—The closure of the renal vein by ligature being immediate and complete.

Exp. 1. The left renal vein of a young weak rabbit was tied, and the animal killed at the end of ten minutes. The bladder was distended with urine, which, when tested by nitric acid and heat, presented permanent flakes. The right kidney weighed 20 grs.; the left 40 grs.

* Six of the experiments on venous obstruction were published in the Medical Gazette of June 1842; but as they serve to render the series more complete, and as the weight of the healthy and engorged kidneys was carefully ascertained, I have been induced to recapitulate them.

Exp. 2. The same operation was performed on a rabbit of similar size and condition, which was killed at the end of half an hour. A smaller quantity of urine was found in the bladder, which when tested by the same re-agents presented a more distinct flakiness. Weight of the right kidney, 26 grs. ; of the left, 51 grs.

Exp. 3. A small weak animal was killed at the end of half an hour after ligature of the left renal vein. There was no urine in the bladder ; the ureter was not examined. The right kidney weighed 26 grs. ; the left, 50 grs.

Exp. 4. An animal of middle size, and in moderate condition, was killed ten minutes after ligature of the vein. There was about a drachm of urine in the bladder, which was highly albuminous. The right kidney weighed 35 grs. ; the left, 70 grs.

Exp. 5. The left vein and ureter being tied, in a young healthy rabbit, the animal was killed at the end of six minutes. The ureter being first carefully wiped, and then divided, the urine contained in it was allowed to drop on a watch-glass, and on being tested with nitric acid, it formed a solid clot. There was a slight appearance of coagulated lymph in the pelvis of the kidney, and a more copious effusion was found beneath its lining membrane. The bladder contained a drachm of urine, which was not albuminous. The right kidney weighed 25 grs. ; the left 50 grs.

Exp. 6. The left renal vein of a middle-sized healthy animal was tied, then the ureter, and ex-

actly three minutes and a half after the ligature of the vein, the artery was secured, and the organ removed. The ureter contained bloody urine. The right kidney was then removed: it weighed 60 grs.; the left, 90 grs. The animal died towards the end of the second day, having previously manifested marked comatose symptoms. No morbid appearances worthy of mention were found.

Exp. 7. In a full grown, strong rabbit, the abdominal aorta was exposed by an incision on the left side of the spine, and seized by a powerful spring forceps. The hinder extremities were immediately paralyzed. The blades of the forceps, the extremities of which were notched, were then separated and withdrawn; but, in taking this step, the coats of the artery became twisted and torn, and considerable hæmorrhage ensued. This was, however, arrested in a few minutes by compression of the trunk above. The left kidney was then drawn out through the same opening, its vein and ureter tied, and the organ returned. The animal seemed at first faint from the loss of blood, but gradually recovered; it was killed at the end of an hour; the paraplegia continuing unchanged till death. The left kidney was much engorged, and presented on its surface several spots of ecchymosis: it weighed 175 grs.; the right kidney, 98 grs. The left ureter contained a coagulum of blood, and above it some muddy brownish fluid, which, on exposure to the air, assumed a bright red tint. The bladder contained nearly two drachms of urine, which was natural in its appearance; and on

being examined, contained no albumen, a few drops of nitric acid rendering it quite clear. The aorta had been torn rather more than two-thirds across; its compression, by the infiltration of the surrounding cellular tissue with a considerable quantity of blood, probably prevented the return of hæmorrhage by obliterating the vessel at that point.

B.—The canal of the renal vein being either partially or slowly obstructed.

Exp. 1. The animal was of middle size, but in poor condition. In tying the vein there was some hæmorrhage from a lateral branch. The animal had previously met with a slight accident, and seemed faint at the time; it was killed at the end of an hour, and the urine in the bladder was slightly but distinctly albuminous. The right kidney weighed 40 grs.; the left, 84 grs.

Exp. 2. In passing a ligature round the vein of a rabbit of middle size, and in moderate condition, the coats of the vessel were torn, and some hæmorrhage occurred, which was soon arrested by compression; it was killed at the end of half an hour. The bladder contained two drachms of urine, which was highly albuminous. The right kidney weighed 50 grs.; the left, 150 grs.

Exp. 3. The left renal vein of a middle-sized weak rabbit was exposed, compressed for a few minutes, and then slightly torn, so as to allow a little blood to escape. The vessel was then securely tied, and the animal killed seven minutes after the

application of the ligature. The urine in the bladder was very slightly albuminous. On dividing the left kidney, the lining membrane of the pelvis was rendered prominent by the deposition beneath, or external to it, of a quantity of clear lymph, in which the larger branches of the vein were imbedded. There was no appearance of lymph in the cavity of the pelvis. The right kidney weighed 42 grs. ; the left, 73 grs.

Exp. 4. In tying the vein of a strong full-grown rabbit, the coats of the vessel were slightly lacerated, so that a little blood continued to ooze out by the side of the ligature. In this state the organ was returned, and the animal killed at the end of an hour. Some urine had escaped through the urethra; but on laying open the bladder, it was found to contain a scruple, by weight, of clear pellucid lymph, which was semi-fluid when first examined, but coagulated more firmly on exposure to the air. The right kidney weighed 100 grs. ; the left, 130 grs.

Exp. 5. A middle-sized animal, in tolerable condition. The left renal vein was tied, and then punctured with a fine needle on the renal side of the ligature, so that some blood escaped in a fine jet. The organ was then returned within the walls of the abdomen, and the animal killed at the end of an hour. The bladder contained about two drachms of bloody urine, which held suspended in it a coagulum of fibrine. This latter was reddened only at one point ; the rest of it being unstained by blood. The pelvis of the kidney also contained a small quantity

of lymph : this organ weighed 90 grs. ; the weight of the right one being 50 grs.

Exp. 6. The left renal vein of a small healthy animal was tied, and then lacerated on the renal side of the ligature. While bleeding freely, the organ was returned, and the animal killed at the end of an hour. The urine in the bladder was not albuminous ; but the upper part of the ureter contained a column of lymph, which, at its lower end, was slightly tinged with blood. The left kidney was considerably enlarged, but the precise weight was not taken.

Exp. 7. In a young healthy rabbit the coats of the left vein were pinched up by a forceps, and so tied that the calibre of the venous canal would be considerably diminished. The animal was killed at the end of forty minutes. The bladder contained about a drachm of urine, which was not albuminous ; but on further examination, the reason of this was apparent ; for the left ureter was found completely obstructed by a coagulum of blood, behind which a quantity of bloody urine had accumulated. Some lymph had also been effused beneath the lining membrane of the pelvis. The right kidney weighed 35 grs. ; the left, 68 grs.

Exp. 8. The left kidney being exposed in a healthy young rabbit, the coats of the vein were pinched up by a forceps, and so tied as materially to diminish the calibre of, without completely obstructing, the venous canal. The organ was then returned, and the animal killed at the end of four and a half days.

The bladder contained a little muddy urine, which was faintly albuminous. The tubular portion of the right kidney was somewhat redder than usual. The left kidney was found enclosed within a perfect cyst of considerable thickness. I could not detect any connection or adhesion between the kidney and its cyst; for the former could be drawn out, and removed without any resistance being experienced: but between it and the interior of the cyst was a thin stratum of purulent looking fluid. This kidney was evidently smaller than the right one; its surface was soft and flocculent, and this looseness of structure extended towards the centre of the organ, becoming, however, gradually less marked. On making a section of it, the tubular portion, in its interior, presented a natural firmness and structure; but it appeared redder than usual, as if it had been lately engorged.

Exp. 9. In a middle-sized strong animal, the right renal vein was exposed, and a ligature tied at such a distance from the vessel as not immediately to impede the flow of blood through the latter. The ureter was also tied. At the end of eighteen hours, the animal was killed. The urine found in the bladder was not albuminous; that in the right ureter seemed nearly pure blood. The left kidney weighed 64 grs.; the right, 182 grs.

Exp. 10. The left renal vein of a full-grown fat rabbit was, in the same manner, included within a loose loop, and the animal killed at the end of an

hour. The bladder contained bloody urine. The right kidney weighed 90 grs. ; the left, 170 grs.

Exp. 11. The left renal vein being exposed, in a small healthy rabbit, the artery was seen to pass obliquely behind it, rendering it very difficult to isolate the former vessel. A thread was passed around both, and tied so as to enclose both within a loose loop. Eight hours afterwards, the animal was alive and well. At the end of twenty-four hours, I found it dead and cold. The left kidney was much enlarged ; it was enveloped in a distinct cyst, apparently formed of the surrounding cellular tissue, which had been infiltrated with blood and lymph. Except at one point, where the kidney had been slightly scratched, there was no adhesion between that organ and its investing membrane ; in fact, they were separated from each other by a small quantity of serous fluid. After reflecting this tunic, an inner one (which I imagined to be the proper capsule) appeared, and, like the former, could be detached from the surface of the gland : thereby proving satisfactorily the real existence of a second membrane. The bladder contained about a drachm of clear urine, which was moderately but distinctly albuminous.

Exp. 12. A precisely similar operation was performed on a rabbit of the same size, the vein alone being included in the loop ; it died at the end of two days and a half. The left kidney was surrounded by a cyst similar to that met with in the

last experiment ; it adhered slightly at one or two points to the capsule ; the latter could be stripped off the kidney, and the separate existence of the two membranes thus manifested. The external surface of the gland presented three or four white spots, resembling those of incipient suppuration or softening. The urine in the bladder was of a faint reddish tinge, and was very highly albuminous.

CLASS II.—*Designed to illustrate the Peculiarities of Arterial Determination.*

A.—Removal of one kidney.

Four animals, of the same age and size, and in similar condition, were selected. The operation was performed at the same time on all of them, and the left kidney weighed at the time of its removal.

Exp. 1. The left kidney of a healthy young rabbit was removed, the vessels being previously tied ; it died at the end of twenty-four hours, partly from the shock of the operation, and partly from peritonitis. The urine in the bladder was not albuminous. The left kidney, when removed, weighed 20 grs. ; the right, 25 grs.

Exp. 2. A similar operation was performed. The animal appeared quite well at the end of the second day, when I poured some cold water over it, with the view of increasing the determination to the remaining kidney ; it seemed unable to bear the shock, and died about the end of the third day. The urine contained no albumen ; but on adding an ad-

ditional quantity of nitric acid, there was a copious precipitation of crystals of nitrate of urea. The left kidney weighed 21 grs. ; the right, 26 grs.

Exp. 3. At the same period, after the operation, this animal was treated in the same manner as the last ; it lived twelve hours longer than it. There was no albumen in the urine ; nor did any deposit of urea take place on adding an equal quantity of nitric acid. The left kidney weighed 20 grs. ; the right, 33 grs.

Exp. 4. Nine days and a half after the removal of its left kidney, this animal appeared quite well ; it was then killed. The bladder contained a small quantity of urine, which yielded a faint cloudiness when treated with nitric acid. The left kidney weighed 21 grs. ; the right, 50 grs.

Exp. 5. The left kidney of a middle-sized strong rabbit was removed, and the animal killed at the end of nine days. The left kidney was unfortunately not weighed ; the right was evidently much enlarged. The urine in the bladder was not albuminous.

B.—Ligature of the aorta, below the origin of the renal arteries.

Exp. 1. In a small weak rabbit, the abdominal aorta was tied, from an incision on the right side of the spine, which added to the difficulty, and, consequently, increased the shock of the operation. There was immediate and permanent paralysis of the hinder extremities. The animal died about ten

hours after the operation. Both kidneys appeared disproportionately large ; each weighed 36 grs., and the tubular portion of each was reddened. The urine was tested with nitric acid. In a small quantity, there was no appearance of albumen ; in a larger, some permanent opacity was produced, not removable by a slight excess of the acid.

Exp. 2. The aorta was tied, from an incision on the left side of the spine, in a middle-sized animal, in poor condition. There was immediate paraplegia, as in the last instance. Some hæmorrhage from the smaller vessels occurred. It was killed at the end of forty minutes. Both kidneys were of a lighter, or more rosy tint than natural ; the tubular portion of each was reddened. The left weighed 4 grs. more than the right ; probably from the lower origin of the left renal artery in this instance. The urine in the bladder was not albuminous.

C.—Ligature of the aorta, and removal of one kidney.

Exp. 1. The aorta of a middle-sized animal, in poor condition, being exposed by an incision in the left lumbar region, it was grasped by a spring forceps of moderate power. The obstruction to the flow of blood was complete, for the artery visibly enlarged above the point of compression. The animal was then liberated, and its hinder extremities were seen to be paralyzed, the useless limbs trailing after the rest of the body. The blades of the forceps were then separated, and carefully withdrawn, and

the animal almost instantly regained the power of moving its limbs. A thread was then passed beneath the aorta, and a knot tied at such a distance from the vessel as not to obstruct the flow of blood. The left kidney was now removed; it weighed 33 grs. On laying it open, the tubular portion was reddened, and on dissecting off the lining membrane of the pelvis, the primary arterial divisions beneath it were seen to be embedded in a quantity of clear lymph. The paralysis of the hinder extremities *never* returned. Four hours after the operation, it was alive, and hopping about. At the end of eighteen hours I found it dead. The right kidney weighed 35 grs. No lymph could be seen beneath the lining membrane of the pelvis. The bladder was distended with urine, which was not albuminous. The ligature hung quite loosely on the aorta, but some bloody lymph had been effused around it.

Exp. 2. In an animal of similar size to the last, and, like it, in very poor condition, the aorta, being exposed, was compressed by the same forceps, and the animal then set free. There was perfect paraplegia. The forceps being separated and withdrawn, it continued to lie in the same position, having its hinder extremities extended and useless, for a few seconds, and then suddenly sprung up with a bound, having perfectly regained the power of moving them. The aorta was then tied tightly, when the paralysis immediately returned, and continued unchanged till death. The left kidney being now removed, weighed 32 grs. ; on laying it open, the redness of the tubu-

lar portion, and the effusion of lymph beneath the membrane of the pelvis, existed as in the previous case. The animal was alive four hours afterwards, and was found dead about eighteen hours after the operation. The right kidney weighed 32 grs., and presented precisely the same appearances as the left. The bladder was full of urine, which contained no albumen.

Exp. 3. The left kidney of a very weak small animal was removed, and the aorta exposed. Some difficulty was experienced in passing a thread around the latter, in consequence of a great quantity of citron-coloured serous fluid accumulating in the wound ; it did not flow from the peritoneal cavity, but was a mere oozing from, or through the vessels. The blood was very poor ; its want of viscidty, as felt by the fingers, was very remarkable. The aorta was tied tightly, producing instantly the ordinary paralysis. The animal was killed at the end of five minutes ; but, from the absence of any unnatural appearance in the right kidney, I did not deem it necessary to examine the urine.

Exp. 4. The aorta of a healthy young rabbit being tied, produced, instantly, permanent paraplegia. The left kidney was then removed, and weighed 30 grs. At the end of eighteen hours, the animal was still alive, but apparently at the point of death ; it was then killed. The right kidney being examined, was reddened in every part of its substance, and presented on its surface some slight spots of ecchymosis, but it only weighed 30 grs. The bladder

contained about a drachm and a half of muddy red urine, which held bloody coagula suspended in it. On testing the liquid portion with nitric acid, albuminous flakes were produced.

Exp. 5. The aorta being exposed, in a young healthy rabbit, was included within a loose loop. The animal continued to run about without any appearance of paralysis. The left kidney was removed at the same time, and weighed 35 grs. Twenty-seven hours afterwards, the power of motion was still unimpaired. At the end of the second day it was found dead. The right kidney weighed 42 grs. On tracing the aorta, it was seen to be embedded in a quantity of lymph, that had been thrown out round the thread, but the canal of the vessel was still pervious. The loop had been applied about half an inch below the origin of the right renal artery, which seemed rather enlarged. The bladder contained nearly two drachms of urine, which was highly albuminous, forming instantly a large coagulum on the addition of nitric acid.

Exp. 6. The aorta of a full-grown strong rabbit was tied tightly, and the left kidney removed; but the ligature round the vessels of the latter having become somewhat loosened, some active arterial hæmorrhage took place. This kidney was of a lighter tint than usual, and weighed 82 grs. The ordinary paraplegia was present. Three hours and a half after the operation, the animal was in the same condition, and was then killed. The right kidney was enlarged and reddened; it weighed 112

grs. The bladder was nearly empty, only two or three drops of bloody urine escaping from it. On tracing down the ureter, its upper portion was dilated to the extent of more than an inch. A coagulum of blood plugged up the lower end of this portion, and on removing it by the division of the tube, a few drops of bloody urine escaped, then some clearer fluid, then a white fibrinous coagulum, and, above all, some twenty drops of clear urine. On allowing the latter to fall into a watch-glass, without any admixture of the bloody urine, and then adding nitric acid, it was found to be very highly albuminous, instantaneous coagulation being produced by this test.

Exp. 7. The left kidney of a middle-sized rabbit, in rather good condition, was removed, and found to weigh 54 grs. The aorta was then tied, without any accident occurring, and was followed by the usual paralysis. This animal seemed to recover from the shock of the operation more quickly than some former ones; it was killed at the end of two hours. The right kidney weighed 85 grs.; it contained six or seven ecchymoses of various extent, in different parts of its substance, but chiefly on the surface; its colour was much lighter than in those experiments in which the engorgement of the organ was produced by venous obstruction. The bladder contained about a drachm of urine, which was bloody and albuminous.