OBSERVATIONS

ON THE

ANATOMY AND PHYSIOLOGY

OF THE

KIDNEY.

BY

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THE difference of opinion which exists, even at the present day, regarding some points connected with the structural anatomy of the kidney, proves, at least, that the investigation of it is not unattended with difficulty. The importance, however, as well as the difficulty of the subject, should be sufficient to convince us of the folly of dogmatizing on a topic upon which the most acute observers have failed to arrive at conclusions in exact accordance with each other. Nor is it wonderful that, in the consideration of such subjects, there should exist different theories concerning the function of an organ, when so much diversity of opinion is met with concerning its structure.

After repeated examinations which I have made of the kidneys of man and other mammalia, both in the uninjected state and injected with materials varying much in consistence, I am inclined to adopt the description of the vascular apparatus of this organ given by Frerichs,* in his admirable monograph on "Bright's Disease," as at

* Die Bright, sche Nierenkrankheit und deren behandlung, 1851.

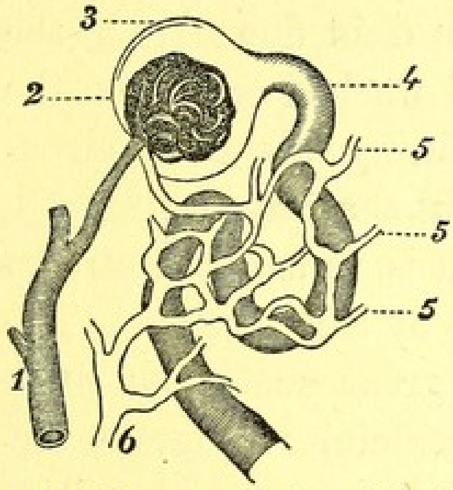
once the clearest and most correct with which I am acquainted. This description which, in all material points, coincides with and confirms the accuracy of that first given by Bowman,* and afterwards supported by the testimony of Johnson,† runs nearly in these words :—" The manner in which the blood-vessels are distributed, and the mode in which the circulation is carried on in the kidney, are of great importance, in order clearly to comprehend the mechanism of its secretion, as well as the pathogenesis of kidney disease. The renal artery, which is equal in circumference to about one-seventh part of the abdominal aorta, divides, immediately on its entrance into the kidney, into several branches, which pass onwards between the pyramids to the cortical substance; these branches, on their way, give off some small twigs, which furnish capillaries to the straight urinary tubules, and are ultimately lost on the boundary between the medullary and cortical portions, in small vessels, of which a small part only passes into the capillary system of the cortex, while by far the greatest part passes on to, and pervades the malpighian capsules. After entering the capsule, the vessel straightway splits up into from three to five twigs, which, in their tortuous course, fill the capsule, and then again converge into one trunk, which a second time pierces the capsule, generally close to the ingoing (afferent) vessel, and thus passes into a capillary plexus, which forms a network around the urinary tubules of the cortex. The twigs which fill the capsule, and thus form the malphigian tuft of vessels, are smaller than the ingoing (afferent) vessel, which latter is usually larger than the outgoing (efferent) vessel ; but, according to Bowman, this is not always the case. The tuft or glomerulus of little vessels fills the cavity of the capsule, and lies naked in it. I agree with Bowman and Johnson in considering that these

* Philosophical Transactions, 1843.

† Cyclopædia of Anatomy and Physiology, Art. 'Ren.' 1848.

vessels are not clothed with epithelium, as Gerlach maintains. The outgoing (efferent) vessels of the malpighian body form a close anastomosing net-work around the tortuous urinary tubules of the cortex. These gradually uniting into larger venous trunks, the blood pursues its course to the renal vein, which leaves the kidney as the artery entered it."

Fig. 1.



The accompanying diagram (fig. 1), copied from Frerich's work, shows at a glance the course followed by much the greater portion of the blood which enters the kidney. (1) Represents the ingoing (afferent) arterial twig, which, entering the flask-shaped dilatation (3), at the extremity of a uriniferous tube (4), breaks up into a capillary tuft or glomerulus (2) ; from this tuft the blood emanates by an outgoing (efferent) vein, which, artery-like, splits forthwith into a capillary net-work (5) of great fineness, whence arises the venous radicals (6) that go to form the renal vein.

Thus it appears that a malpighian body is constituted by a tuft of vessels lying naked in the dilated termination of a uriniferous tube, forming *the capsule.* The blood enters this body by a small artery, and leaves it by a small vein, which can, with the utmost ease, be injected from the artery ; even the outgoing vein, and the net-work in which it loses itself, can be filled with thin injection thrown in from the artery. Nay more, a thin injection thrown in in this direction (that is, the direction in which the blood flows during life), flows oftentimes without difficulty from the renal vein. But no injection, however fine, have I been able to throw in, in a retrograde course (that is, from the vein), so as to fill the vessels of the malpighian body. This fact, observed by Bowman in his paper already alluded to, he explains by the mechanical obstruction offered by the capillary net-work (5), through which the injected fluid must pass, when thrown in from the vein, before it arrives at the malpighian tuft of vessels.

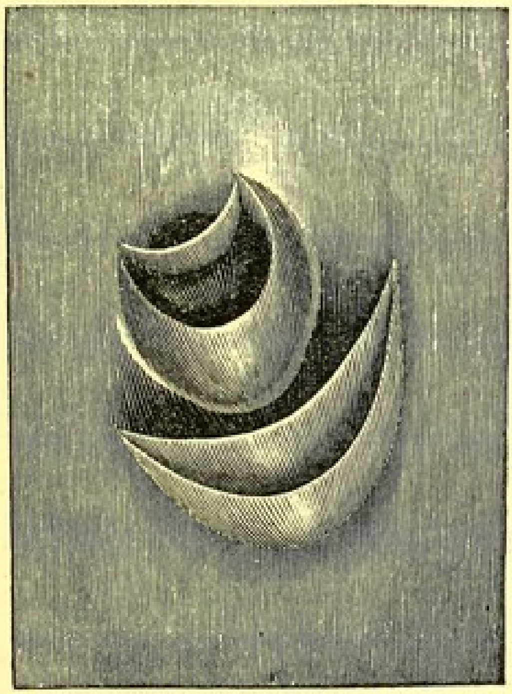
What the true explanation of this fact may be, I am not prepared to state ; but I cannot consider that just quoted as satisfactory. I have passed a gentle stream of water into the artery of a kidney, so as to establish an artificial circulation. After a little time, the fluid flows from the vein deeply coloured with the blood washed out from the vessels of the organ. After maintaining this water circulation for a sufficient time to clear out the contained blood, I have tried to reverse the flow, that is, to pass the stream of water in by the vein and out by the artery. The kidney, in consequence, swells to a great size ; but even great pressure will not effect an artificial retrograde circulation. I have tried the same experiment with spirits of turpentine, spirit of wine, and other subtile fluids, with almost constantly the same result. As to the possibility of filling the capsule of the malpighian body with fluid injected from the pelvis of the kidney, I have never succeeded in doing it, although I have oftentimes filled the tubes as far back as the surface, which is readily done in the kidney of the horse. I therefore agree with Bowman as to the difficulty of effecting this, although I cannot agree with him as to its impossibility. Toynbee's assertions seem too circumstantial to be devoid of truth ;* and, moreover, I have in my possession a preparation made by Professor Hyrtl, of Vienna, and thus labelled by that eminent anatomist—"*Sectio renis hominis, injecta in pelvim renalem materia alba usque in capsulas malpighianas progressa est.*" The sessile dilatations connected with the tubuli uriniferi, mentioned by Gerlach,† I have never seen.

* Medico Chirurgical Transactions, vol. xxix.

† Müller's Archiv., 1845.

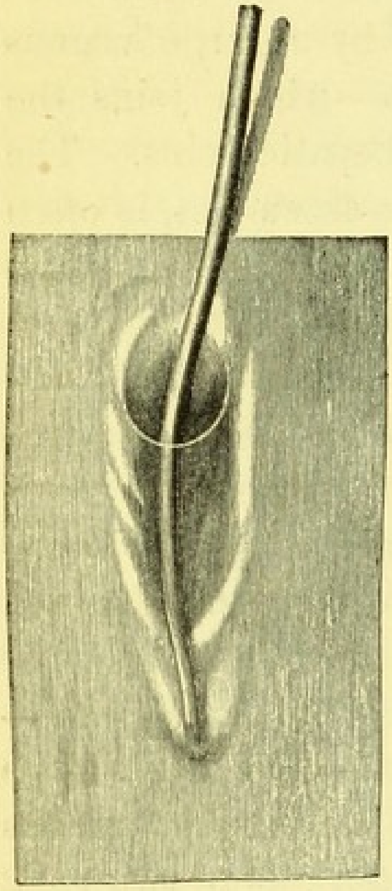
The following account may be given of the circulation in the kidney :—A stream of blood is directed to the kidney through an artery, very large in proportion to the size of the organ it goes to supply, and with considerable force, inasmuch as that vessel arises from the aorta at no great distance from the heart. The blood, while circulating in the gland, passes through a double system of capillary vessels: first, in the corpora malpighii; secondly, in the anastomosing network on the walls of the uriniferous tubes, and ultimately makes its exit by a large venous trunk—the renal or emulgent vein—which joins the ascending cava some way below the hepatic veins. The renal vein, at its junction with the cava ascendens, is often guarded by a valvular apparatus, which merits special attention, and which is here represented as met with very frequently, if not constantly, in the horse (fig. 2), and sheep (fig. 3), and occasionally in man (figs. 4 and 5). This valve, which is composed, like the valves of veins generally, of a very delicate but tolerably strong membrane, I have never observed to be altogether wanting in the horse. It is usually very complete in that animal. In the woodcut (fig. 2) this apparatus is represented ; here two *right* renal veins existed, each guarded by two semilunar folds of membrane, the free falciform margins of which look towards the heart. Fig. 3 represents the same as seen in the sheep, in which it seems to be rarely, if ever, deficient, although not always at the mouth of the vein, as here figured. Figs. 4 and 5 show the same as sometimes met with in the human renal vein ; fig. 4 represents the valve as seen on looking into the mouth of

Fig. 2.



the renal vein from the cava. It consists of two semilunar folds of membrane, one inside the other ; the inner one, when fully stretched, forming a complete expansion across the mouth of the vein it guards. Fig. 5 is the same, the outer fold of membrane being divided so as entirely to expose the inner one. In figs. 3 and 5 the probes are passed behind the membrane forming the valve, and from the cava into the renal vein.

Fig. 3.

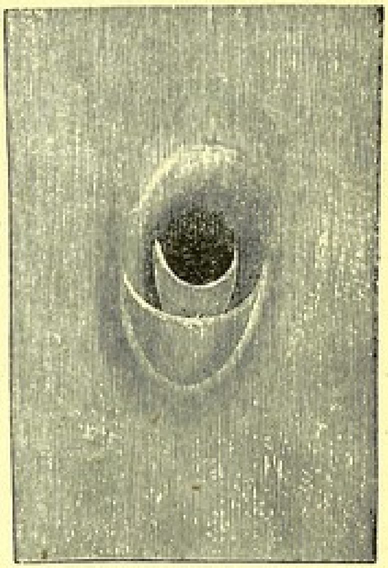


The office of this valve is sufficiently obvious. It prevents, more or less completely, according to its condition of development, a regurgitation of venous blood from the cava to the kidney, and consequent venous congestion of that organ ; an occurrence which must otherwise readily take place from valvular disease of the heart, or any other lesion causing retarded venous circulation.

It may be supposed that, while the stream of blood is flowing in its normal course along the cava ascendens towards the heart, these valves prevent the blood of the extremities from entering the renal veins ; but that, if a current be supposed to pass in a retrograde course down the cava ascendens, this valvular apparatus, by flapping out towards the middle of the cava, would favour the passage of the venous blood into the mouths of the renal veins. The examination of the valve in the recent state is sufficient to refute at once any such idea. The fineness and delicacy of the membrane composing the valve is such, that any current, however feeble, entering the mouth of the renal vein, must carry the membrane with it, and so close, or help to close, its orifice.

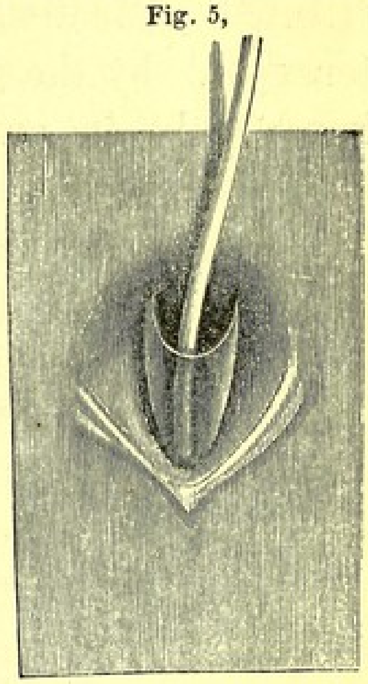
Particular attention seems due to this valvular apparatus: first, because its presence or absence cannot but be regarded as of importance in the consideration of renal disease, its deficiency no doubt predisposing to congestion, and consequent chronic disease of the kidney; and secondly, in order to refute certain physiological theories, no less novel than startling, and coming from so high an authority as the justly celebrated French physiologist, Claude Bernard.

Fig. 4.



According to Bernard,* there exist channels of anastomosis between the vena porta and the cava ascendens. These anastomosing vessels enter the cava behind the liver, and at the lower part of that portion of the cava which lies in contact with the liver. During digestion, the greater part of the portal blood coming from the intestines, and charged with nutritive, as well as not unfrequently with deleterious materials, enters the liver, there to be subject to its purifying influence, before mixing with the general current of the circulation. Part, however, of the portal stream passes through the anastomosing channels directly into the vena cava ascendens; and this must likewise be purified by glandular action before it is allowed to pervade the system. Bernard, therefore, asserts† that "There exists in that portion of the inferior cava which lies behind, and is below the orifices of the hepatic veins, a muscular coat of considerable thickness, the contractions of which

Fig. 5,



* Archives Générales de Mèdicine, vol. xxiii.

† The Physiological Researches of Claude Bernard. By Harvey Ludlow, Esq. Brit. and For. Med. Chir. Review, January, 1854.

cause the cava and renal veins to pulsate during digestion, the pulsations not being synchronous with those of the heart. In addition to this muscularity, the inferior cava of the horse presents two valves, attached to its wall immediately below the orifices of the renal veins. Now the consequences of this arrangement are as follow :—During digestion the liver becomes congested, the portal blood regurgitates, and would stagnate but for the existence of chanels enabling it to pass into the inferior cava below the orifices of the hepatic veins. The blood thus diverted is not permitted at once to mingle with the general circulation, before being submitted to glandular action. The muscular coat of the inferior cava contracts, and greatly diminishes its channel ; the impeded blood is thus thrown backwards on that ascending from the limbs, but the valves below the orifices of the renal veins prohibit further regurgitation, and it is compelled to flow off right and left by the renal veins to the kidneys, which eliminate from it such materials as are excessive and pernicious ; and so the 'urina cibi' is constituted. Meanwhile the order of the circulation is interrupted by the arrest of the blood ascending from the lower limbs, in consequence of the closure of the valves below the renal veins ; but this disturbance is provided for by the existence of the vena azygos, which receives the impeded blood, and conveys it to the superior cava.

" Such are the views of Bernard respecting the hepatico-renal circulation.* He adduces three notable experiments to support them. In the first, cyanide of potassium, mixed with carbonate of soda, was introduced into the stomach of a rabbit, and in ten minutes the urine exhibited the characteristic blue, on the addition of a few drops of solution of acetate of iron. At the expiration of half an hour the animal was killed, and blood col-

* American Journal of Medical Sciences, July, 1851.

lected from both jugulars and both renal veins ; the serum from the former furnished scarcely a trace of the presence of the salt, while that from the renal vessels contained a large quantity. A strong blue colour was also produced by the application of a solution of iron to the cut surface of the kidney ; while a similar proceeding was followed only by a faint tinge when applied to other organs.

"In the second experiment, a solution of cyanide of potassium, in the proportion of 20 parts of the salt to 100 of water, was thrown into the mesenteric vein of a rabbit. The urine in a few minutes contained a large quantity of the salt, but the animal suffered no inconvenience from its presence in the portal blood. When, however, a solution containg 2 parts of the salt to 100 of water, was thrown into the jugular vein, the animal died in a few minutes, before the slightest trace of the poison could be detected in the urine.

"A solution of lactate of iron was injected into the subcutaneous cellular tissue on the back of a rabbit, and a solution of prussiate of potash into the cellular tissue of the thigh of the same animal. In a few minutes a blue colour was manifested at the spot occupied by the solution of iron. But when the prussiate of potash was administered by the stomach, and the solution of lactate of iron placed, as before, under the skin of the back, no blue colour was developed in that situation ; and while the urine was found by tests to contain a large quantity of the salt, the serum of the jugular vein manifested but slight traces of its presence."

As regards the anatomical points here put forward, there is no doubt that in man and many other animals, especially in the horse, the coats of the vena cava become greatly thickened where this vessel is in contact with the posterior part of the liver. This thickening is chiefly composed of condensed fibrous tissue, with abundance of yellow elastic fibres intermingled. It varies much in thickness in different horses ; and soon after death it contracts, so as to throw the lining membrane of the vein into longitudinal folds.

As to the valvular apparatus, an examination of it in the horse, or, perhaps better, in the sheep, will be sufficient to convince the observer that it is not adequate to perform the function assigned to it by Bernard. In order, however, to place this beyond doubt, I have injected, by means of the double injection (saturated solution of bichromate of potash and acetate of lead, thrown in one immediately after the other), the vena cava of a rabbit from below towards the heart, having tied the vessel above the diaphragm. The injection, which passed readily into the liver so as at once to make it quite yellow, frequently did not make its way to the kidney at all ; and when it did, by some curious coincidence, it was found more rarely in the left than in the right, in the rabbits experimented on. The same result followed when the fluids were thrown down the cava from the heart. However, then, Bernard's experiments are to be explained, it cannot be by an "*hepatico-renal circulation.*"

In repeating his experiments, I have not been fortunate enough always to succeed in obtaining the same results as this distinguished physiologist ; nor can failure be accounted for by want of care in their performance, or want of accuracy in the preparation of the solutions. In the first, in which cyanide of potassium mixed with carbonate of soda is introdued into the stomach, the animal dies in a few minutes, if the solution be strong ; and if it be sufficiently weak not to kill at once, the amount is too small to be detected in the blood. As to the second, I have found the weak solution of cyanide of potassium (2 per cent.) equally fatal, whether injected into the jugular or mesenteric vein, in rabbits operated on, both when fasting and during digestion, producing death in from four to ten minutes. In the third, where prussiate of potash and lactate of iron solutions are thrown into the subcutaneous cellular tissue, in different parts of the same animal, a blue colour is soon observed at the seat of the iron injection, becoming very marked in the course of half an hour, and the urine is found to contain prussiate of potash abundantly, turning blue on the addition of some drops of the lactate of iron solution. If at the end of half an hour the animal be killed, and some of the serum of the blood, of the urine and of the bile, be tested with solution of lactate of iron, a great abundance of prussiate of potash is detected in the urine, much less in the serum, and none at all in the bile. If, also, a drop of the iron solution be applied to the cut surface of the lung, liver, pancreas, parotid gland, and kidney, while in all of these organs traces of the prussiate are discovered, the kidney alone becomes of a deep-blue colour. The same test applied to the mucous surface of the alimentary canal shows a trace of the prussiate of potash at the pyloric extremity of the stomach, before any can be detected in the duodenum, ilium, or cœcum. This experiment merely proves the *elective* power that the kidney exercises in selecting certain matters for elimination of the blood. When prussiate of potash is introduced into the blood by the way just mentioned, it of course pervades the whole of the circulating fluid, and in its course through the system is laid hold of by the kidney for elimination, which function is performed by that organ with surprising activity. When, however, a solution of lactate of iron is thrown into the subcutaneous cellular tissue on the back of a rabbit, and a solution of prussiate of potash introduced into the stomach, the same solutions and equal quantities being used as in the last experiment, no blue colouring occurs at the seat of the iron injection ; nor on killing the animal at the end of half an hour, is any of the prussiate of potash to be detected in the serum of the blood ; the urine contains the salt but sparingly, and neither the kidney nor any other organ exhibits the least tinge of blue on the application of the solution of lactate of iron-

The same was the result when the animals so treated were allowed to survive many hours.

This experiment does not seem to prove that the prussiate of potash, absorbed by the stomach and thus entering the portal blood, was got rid of through the agency of the *hepatico-renal* circulation; for once absorbed into the blood of the portal system, assuming for a moment the truth of Bernard's theory, the greater part of it would pass on through the liver, and thus enter the general circulation, since Bernard* does not seem to think that this salt is capable of elimination in the bile, a fact supported by what has been already stated. The fact seems to be, that the yellow prussiate of potash, when taken into the stomach, is not absorbed into the system so rapidly as when injected into the subcutaneous cellular tissue. It thus enters the circulation more gradually, and is got rid of by the kidneys as fast as it is absorbed. I have myself swallowed considerable doses of this salt (ʒij to ʒiv) in solution. It is soon to be found in the urine, by the addition of lactate of iron and a few drops of nitric acid, and continues for some days to be thus eliminated. I have not discovered it in the saliva, nor have I been able to detect more than the least trace of it in the serum of an ounce of blood drawn from the arm.

Some of the most remarkable of Bernard's own experiments are at variance with one another on this subject. Thus he states that " a solution of the albumen of eggs, injected into the jugular vein of a dog or rabbit, appears after a short time in the urine ; but if a similar solution be thrown into a branch of the portal vein, the urine undergoes no change in its composition ; proving that an alteration is effected in the albumen during its transit through the liver, adapting it for the nutrition of the tissues."† Why should not some of the albuminous so-

* Archives Générales de Mèdecine, January, 1853, and Glasgow Medical Journal, April, 1853, p. 118.

† Brit. and For. Med. Chirurg. Rev. p. 65.

lution, thrown into the mesenteric vein, pass through the "anastomosing channels" directly into the cava, and being thus conveyed to the kidney, be excreted, just as that thrown into the jugular vein?

The important physiological discoveries which Claude Bernard has already made, give great weight to any assertion of his, and on this subject I am induced to differ from him, from the conviction that he has formed his conclusions too hastily, and has, perhaps rather rashly, given the sanction of his name to a theory, which, had it emanated from a less high authority, would have hardly deserved to be so fully analyzed.

Robinson's* experiments "illustrating the effects of venous obstruction on the kidney and its secretion," which have the advantage of having been repeated and confirmed by Frerichs† prove that not only does bloody or albuminous urine in all cases follow such obstruction, but, as a consequence of it, the kidney enlarges rapidly to a great size. Thus, in a greater number of the cases in which he applied a ligature to the renal vein in rabbits, bloody or albuminous urine immediately resulted; and on killing the animals in from ten minutes to half an hour, the kidney of the side operated on was found to weigh *twice* as much as the sound one. With these observations those of Frerichs closely agree. In the section of his work devoted to "experimental proofs of the origin of Bright's disease from venous congestion," he states that, in an old rabbit in which the left renal vein was tied, after twelve hours the urine was found bloody and highly albuminous, the left kidney was more than double the weight of the right, and the urinary tubules were filled with blood. An increased supply of arterial blood does not, according to these physiologists, give rise to these consequences in so marked a degree as venous congestion. After applying a ligature to the aorta, immediately below the origin of the

* Medico-Chirurgical Transactions, second series, vol. viii. p. 56.
† Die Bright, sche Nierenkrankheit, p. 276.

renal arteries, so as to turn a strong arterial current to the kidneys, Frerichs says, " only in a few such cases could I discover traces of albumen. The extirpation of a kidney (which causes a determination of blood to the other) produces this result in a very slight degree. The kidney may, after the course of ten days, double its weight ; but albuminuria does not follow." These facts plainly show the importance of the valvular apparatus found to exist in the renal vein, usually at its opening in the cava, the evident use of which is to obviate venous congestion of this important organ.

In treating of the diseases of the kidney, it should always be borne in mind that albuminuria is not a disease, but a symptom—a symptom, also, which physiological research has proved to be dependent on the most opposite causes ; for, independently altogether of any *organic* affection of the kidney, albuminuria may result from particular conditions of the blood and its albumen.* Kierulf has lately shown that considerable dilution of the blood with water is followed by the secretion of albuminous urine. Vogel† has observed that the respiration of arseniuretted hydrogen gas so acts on the blood, as to cause the flow of dark-coloured urine containing albumen; and Bernard has proved, in the experiments before alluded to, that the kidney has the power of selecting for elimination albumen thrown into the veins of the neck, and which, consequently, has not been so assimilated as to suit it to be retained in the system. No doubt venous congestion is in many cases the starting point of chronic renal disease, accompanied by albuminuria, with deficiency of the normal salts of the urine, and especially of urea ; and, as is well known, many of the alarming symptoms met with in such disease are due to this retention of urea in the blood. Hence much practical importance is to be attached to the researches of Bernard

* Zeitschrift für ration. Med. Von. Henle und Pfeiffer, 1853, p. 279.
† Archiv. des Vereins, 1853, Heft 2.

and Barreswil,* regarding the mode of elimination of urea after extirpation of the kidneys, from which they conclude that the urea is got rid of by the secretions of the intestinal canal, and chiefly as an ammoniacal salt in the gastric fluid after such extirpation. This is a fact, which not only explains in some degree the tendency to gastric irritation and diarrhœa in Bright's disease, but also suggests an idea concerning the treatment of threatened uræmic poisoning, which is well worthy of attention.

The practical value of these facts will be sufficiently appreciated by those who agree with Marshall Hall in thinking, that, "to become good and enlightened practitioners, we must become able physiologists."

* Sur les Voies d'Elimination de l'Urine après Exterpation des Reins. Arch. Gen. de Med. 1847, p. 449.

THE END.