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Nephrology Dialysis Transplantation

Historical Note

(Section Editor: J. S. Cameron)

William Cruickshank (FRS – 1802): Clinical chemist

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Introduction

I was researching the start of modern urinalysis, which began at the end of the eighteenth century. In 1764 Cotugno [1] had shown that urine from a case of nephrotic syndrome produced a 'white coagulum similar to that of boiled egg white'. A William Cruickshank was credited with first describing 'the nitric acid test for protein'. I looked Wm. Cruickshank up in several dictionaries of Biography [2] and was rather surprised. Physicians are familiar with the immense skill, learning, and culture of surgeons—but Wm. Cruickshank seemed to have been an extraordinary polymath by any standards. He was surgeon, anatomist, chemist, and physicist. Moreover, he either worked extraordinarily hard or seemed to be able to be in two places at once. 'My' Cruickshank, who studied urine, was spelt with a c, and yet the anatomist part of my man was usually spelt without a c. It became clear that there were two Wm. Crui(c)kshanks, who lived and practised in London at the end of the eighteenth century, were made Fellows of the Royal Society (FRS) within five years of each other, and both died at the beginning of the 1800s. After their death they were 'amalgamated' into one man—and Wm. Cruickshank, surgeon and chemist to the Woolwich Arsenal, who did important pioneer work on proteinuria, disappeared without trace. The other, William Cumberland Cruikshank [3], anatomist and surgeon, is well documented and died in 1800.

William Cruickshank

William Cruickshank [4] Dipl. RCS (England) 1780, was Ordinance Chemist and Lecturer in Chemistry (1795) at the Royal Artillery Academy at Woolwich, and Surgeon of Artillery, and Surgeon to the Ordinance Medical Department. Elected a fellow of the Royal Society (FRS) in 1802, he died in Scotland *c.* 1811.

Sadly we know nothing at all of Cruickshank's early life or how he arrived at Woolwich Arsenal. This was the government's centre for 'Defence research and development' and much of Cruickshank's work would have been on explosives, although almost nothing is known of this research. It is interesting that his contemporary Lavoisier, father of French chemistry, was appointed in 1775 to his government's munitions factory.

Cruickshank's work can be broadly divided into chemistry and analytical chemistry applied to clinical medicine, and basic chemistry which included his work on explosives and electrolysis. When he first arrived at Woolwich, he was appointed assistant to Dr Adair Crawford [5]. Adair Crawford (1748–1795, FRS 1786) was a physician to St Thomas' Hospital, and lecturer in Chemistry at Woolwich Arsenal. He was assisted by Cruickshank in the discovery of strontium (Sr) [6]. Strontium was purified by Davy in 1814 using electrolysis.

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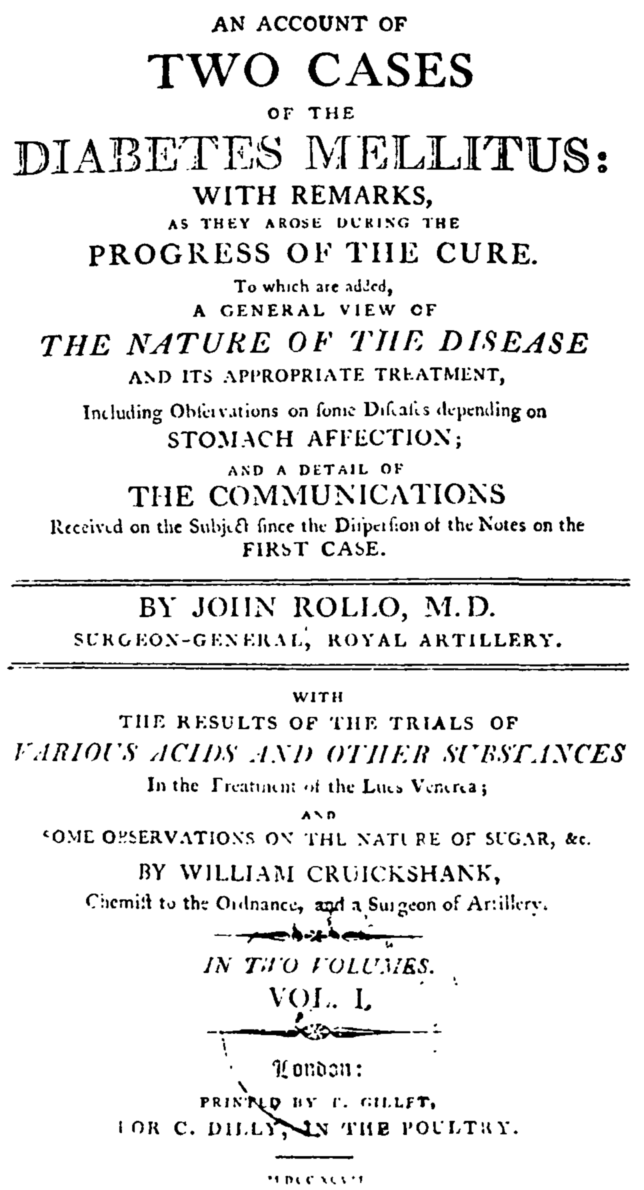
Medicine

At the Royal Artillery Hospital, Woolwich, Cruickshank worked under the Surgeon-General John Rollo. In 1797 Rollo published a popular and well-circulated book 'An account of two cases of the diabetes mellitus' (in two volumes), with a second edition (in one volume) in 1798; and the two editions of his book on diabetes incorporate Cruickshank's research on diabetes, urine analysis, venereal disease, and disinfection by fumigation (Fig. 1). The second edition contains much correspondence from other physicians regarding the first edition, and it is clear that, although diabetes was well known to physicians, most only had personal experience of one or rarely two cases.

Urine analysis

In the last years of the 1790s Cruickshank was extensively analysing the chemical components of urine in health and disease. The following are a few of his remarkable observations published in the second edition of Rollo's book [7].


AN ACCOUNT OF
TWO CASES
OF THE
DIABETES MELLITUS:
WITH REMARKS,
AS THEY AROSE DURING THE
PROGRESS OF THE CURE.
To which are added,
A GENERAL VIEW OF
THE NATURE OF THE DISEASE
AND ITS APPROPRIATE TREATMENT,
Including Obfervations on fome Difeafes depending on
STOMACH AFFECTION;
AND A DETAIL OF
THE COMMUNICATIONS
Received on the Subject fince the Difperfion of the Notes on the
FIRST CASE.

BY JOHN ROLLO, M.D.
SURGEON-GENERAL, ROYAL ARTILLERY.

WITH
THE RESULTS OF THE TRIALS OF
VARIOUS ACIDS AND OTHER SUBSTANCES
In the Treatment of the Lues Venerea;
AND
SOME OBSERVATIONS ON THE NATURE OF SUGAR, &c.
BY WILLIAM CRUICKSHANK,
Chemift to the Ordnance, and Surgeon of Artillery.

IN TWO VOLUMES.
VOL. I.

London:
PRINTED BY C. GILLET,
FOR C. DILLY, IN THE POULTRY.

Fig. 1. Frontpiece to the 1st edition of *An account of two cases of the diabetes mellitus.*

The urine contains neutral salts and animal extractive matter. There is an enormous daily variation in health and disease. The specific gravity varies between 1005 and 1033 (distilled water at 1000). On exposure to air putrefaction occurs, with the production of much ammonia. When first voided urine always contains an excess of phosphoric acid held in solution as phosphate of lime, and readily thrown down by fixed alkali or even pure ammonia. Urine reddens litmus. Evaporation of 36 oz (c. 1000 ml) yields a residuum of 1–1½ ounces (50 oz = 1450 ml) this consists of muriats of potash and soda (KCl, NaCl), phosphoric and lithic acid (uric acid) and animal extractive matter ... (p. 240)

... Lithic acid and nitrous acid (nitric acid) evaporated to dryness leaves a bright crimson colour. Calcium phosphate and nitric acid yields a white colour ... (p. 241)

Pure ammonia and fixed alkalies dropped into healthy recent urine, produce a slight cloud, which, on examination, will be found to consist principally of phosphate of lime; about 2 gr may be obtained in this way from 4 oz of urine. Lime water likewise throws down a precipitate which is much more copious, for reasons which must be obvious.[1] Nitrous acid, added to healthy urine, produces a slight effervescence, and gives it more or less of a reddish colour, but produces no precipitation. In some diseases, however, particularly general dropsy or anasarca, this reagent, when dropped into the urine, produces a milkiness, and in some instances a coagulation, similar to what would take place if added to the serum of the blood. When bile is mixed with this fluid, as in jaundice, the acid renders it green.

The principal of tan, or infusion of oak-bark, detects animal mucilage or jelly, and the quantity of coagulum thrown down will in general bear a certain proportion to the extractive matter. Four oz. of healthy urine afforded in this way precipitates of about 4 gr.

The corrosive muriat of mercury is a very useful reagent, as it has no immediate effect on recent healthy urine; but in every case of increased action of vessels, more particularly of the inflammable kind, a greater or less milkiness, and a whitish precipitate, is instantly produced; it likewise in some degree coagulates dropsical urine.—Effects somewhat similar, although not so striking, are produced by alum. The muriat of barytes detects the phosphoric salts. ... (From pp. 243–244)

Upon the whole, therefore, we would observe, that the proportion of extractive matter, may in some measure, be determined by an infusion of oak bark, or rather galls; the quantity of phosphoric salts by the muriat of barytes, or acetite of lead; that of the muriatic salts by the latter substance; the proportion of phosphate of lime by pure ammonia, or any of the alkalis, and the lithic acid by the processes already described. In morbid states of the urine, the coagulable part of the serum is detected by the nitrous acid, and even by heat; bile by the nitrous or muriatic acids; and the condition of urine accompanying rheumatism and other inflammatory complaints by the corrosive muriate of mercury and sometimes by alum ... (p. 245)

From what has been delivered it must be evident, that an attentive examination of the urine may lead to useful conclusions in several diseases.

In dropsy, the general disease may readily be distinguished from that depending on morbid viscera, by attending to the effects produced on this fluid by nitrous acid and the corrosive muriat of mercury. In three cases which we have lately met with, the urine coagulated not only on addition of nitrous acid, but likewise by heat; and, in one of them, which proved fatal in six weeks, the urine appeared to differ but little from the serum of the blood, so remarkable was the coagulation produced by heat and acids ... In the dropsy proceeding from diseased liver and other morbid viscera[2], the urine does not coagulate either by nitrous acid or heat; it is usually small in quantity, high coloured, and deposits, after standing, a considerable quantity of pink-coloured sediment. This

[1] Cruickshank clearly expected his readers to follow what he was saying—without him having to explain every implication. My reason for this emphasis will become clear.

[2] The point is that Cruickshank is assuming that the reader realizes that he was discussing the kidney, and now he is discussing other organ pathology. Thus Cruickshank can claim to be the first to demonstrate that heavy proteinuria causing dropsy was due to kidney disease.

peculiar sediment we consider as, in some measure, characteristic of diseased or rather scirrhous liver. On examination we found that it consisted of a phosphate of limes, some animal matter to which its red colour was probably owing, and a little lithic acid; this last, however, was in very small quantity. In inflammatory affections, particularly those of the chest and acute rheumatism, the urine, during the active state of the disease, always affords an immediate precipitate with the corrosive muriat of mercury or alum, and sometimes with the nitrous acid—when the disease takes a favourable turn, this effect will in a great measure cease, and the 'lateritious sediment makes its appearance. (pp. 248–249)
We have thrown out these imperfect hints, merely with a view to induce others to pay some attention to a subject which has of late been much neglected, but which, in our opinion, is capable of affording great assistance in the investigation and cure of many diseases. (p. 256).

In 1797 Cruickshank produced urea nitrate by adding concentrated nitric acid to evaporated urine.

Work on sugars

Cruickshank must have been one of the first analytical chemists to investigate the composition of organic compounds and was particularly interested in sugars. He was fascinated by the chemistry of fermentatation and in a series of definitive experiments, using different atmospheres, showed the absolute requirement for oxygen [8].

Disinfectants

In 1795 Wm. Cruickshank introduced chlorine into Woolwich Military Hospital as a disinfectant [9] (Fig. 2). In 1780 Sir James Carmichael Smyth had used nitric acid vapour to purify contagious ships. The latter, however, was generally felt to be more dangerous than the contagion.

Treatment of syphilis

At this time there was enormous enthusiasm about the power of oxygen to treat clinical disease. Cruickshank, and others, were particularly interested in the idea that oxidizing agents could be given as therapy and in the first edition of Rollo's book he proposed that such chemicals might be efficacious in the treatment of syphilis. The second edition is full of enthusiasm and individual case details of the great success of this therapy: nitric acid (1 drachm diluted in 20 oz of water), and oxygenated muriate of potash (potassium chlorate) being particularly successful and more effective than citric acid [10] (Fig. 3). The potassium chlorate (now known to be a highly toxic proximal renal tubule toxin) resulted in a gratifying increase in urine flow after a few days! These ideas may seem odd now, but 200 years later we are equally obsessed with trying to deliver nitric oxide, in similar ways, to obscure parts of the body.

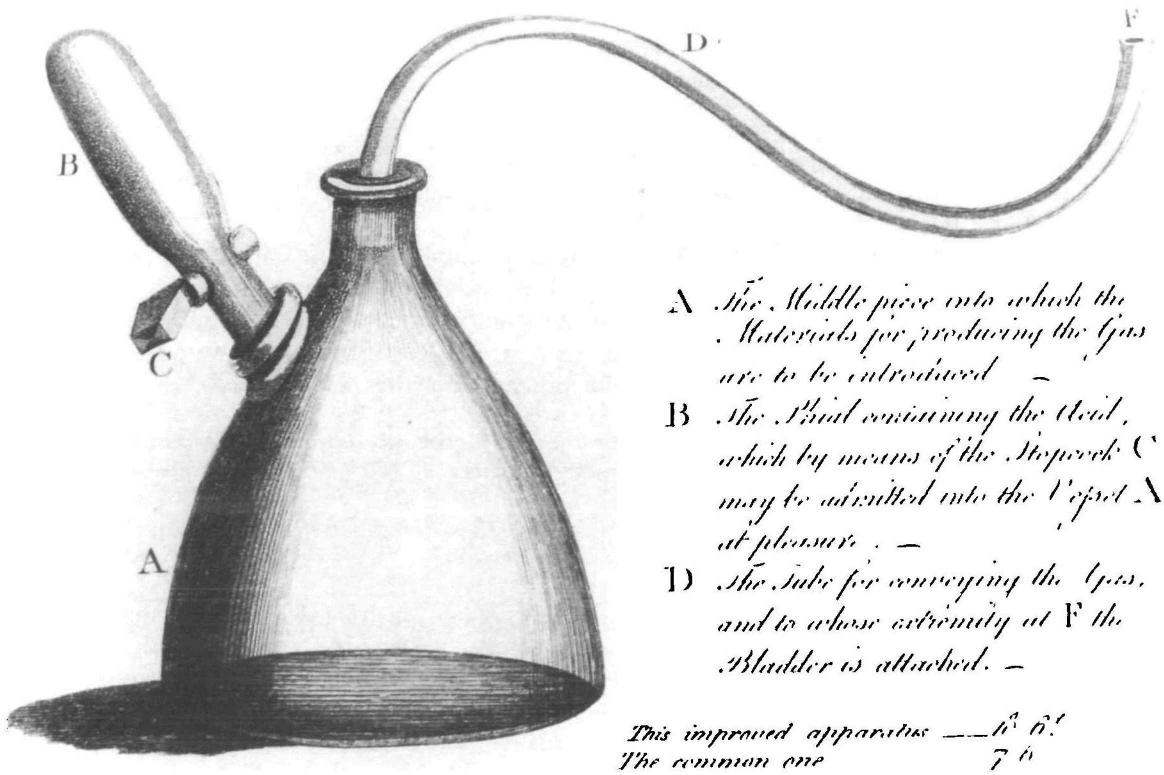


Fig. 2. Apparatus used for fumigation.

Battalion	Men's Names.	Nature of the Diſeaſe.					Particular Remedies employed.	By whom treated	Period of Admiſſion and Diſcharge.	
		Chancre	Bubo	S. Throat	Eruptions	Node			Admiſſion.	Diſcharge.
1ſt	Sherrar —	—	1	—	—	—	Acid Nitros — —	Ja	Mar. 10, 1797	April 26, 1797
	Evans — —	1	—	—	—	—	Do. — —	Ja	10, do.	16, do.
	More — —	1	—	—	—	—	Do. — —	Ja	10, do.	19, do.
	Clarke —	1	—	—	—	—	Do. — —	Ja	10, do.	11, do.
	Beats — —	ſeveral	—	—	—	—	Kali ox. mur. —	C	May 8, do.	May 26, do.
	Smith —	do.	1	—	—	—	Acid nitros — —	Ir	June 28, do.	Aug 14, do.
	Devenport —	—	1	—	—	—	Do — —	Ir	Sept. 8, do.	Oct. 14, do.
	Henderſon —	deep	2	—	—	—	Kali ox. mur. —	Ir	Nov. 10, do.	Jan. 8, 1798
	Hart — —	ſeveral	—	—	—	—	Do. ung. hydr. calomel	Ir	11, do.	Dec. 25, 1797
	Muddling —	1	—	—	—	—	Kali ox. mur. —	Ir	Aug. 23, 1798	Sept. 24, 1798
2d	King —	ſeveral	—	—	—	—	Kali ox. mur. —	C	Mar. 8, 1797	June 30, 1797
	Smiley —	do.	—	—	—	—	Acid nitros — —	C	12, do.	April 3, do.
	Middleton —	1	—	—	—	—	Do. — —	C	15, do.	18, do.
	Fernſide —	deep	—	—	—	—	Do. kali ox. mur. —	C	May 29, do.	July 1, do.
	Johnſtone —	ſeveral	—	—	—	1	Acid nitros. kali ox. mur.	W	Aug. 22, do.	April 4, 1798
	Wardley —	1	—	—	—	—	Ox. mur. of manganeſe —	W	28, do.	Sept. 19, 1797
	Fowler —	1	—	—	—	—	Do. — —	W	29, do.	Dec. 12, do.
	Porter — —	1	—	1	—	—	Do. kali ox. mur. —	W	Sept. 10, do.	Jan. 13, 1798
	Wardly —	Excor^s.	—	—	—	—	Kali ox. mur. —	W	Dec. 1, do.	Dec. 11, 1797

Fig. 3. Clinical cases treated for Lues (2nd edition).

Chemistry

Work on gases

Cruickshank prepared carbon monoxide by passing carbon dioxide over heated iron. He called it 'gaseous oxide of carbone' and described it as '*heavy*, inflammable air' and correctly proposed its composition as CO. Dalton's theory of 1803 that matter consisted of 'atoms' was in part inspired by Cruickshank's accurate description of carbon monoxide.

The famous chemist Joseph Priestley (1733–1804) refused to believe Cruickshank's work, and subsequently there was a robust exchange of correspondence between Priestley and Cruickshank, which continued after Priestley moved to North America [11]. Another modest Yorkshire man, he wrote of himself:

'No person was ever more temperate, or more cautious than I have been in the introduction of new terms, considering the number of new facts that I have discovered'.

Work on electrolysis

In March 1800, Volta had written a letter to Sir Joseph Banks, President of the Royal Society, describing his invention of the (Voltaic) Pile. This was read at a meeting of the Royal Society on 26th June. Cruickshank constructed a trough battery [12] in July and September 1800.

...a kind of trough of baked wood, 26 inches in length, 1.7 inches deep, and 1.5 inches wide; in the sides of the trough, grooves were made opposite to each other, about the tenth of an inch in depth, and sufficiently wide to admit one of the plates of zinc and silver when soldered together; three of these grooves were made in the space of one inch and three tenths, so that the whole machine contained 60 pairs of plates. A plate of zinc and silver, each 1.6 inches square, well cemented together, were introduced into each of these grooves or notches, and afterwards cemented into the trough by a composition of rosin and wax, so perfectly, that no water could pass from one cell to the other ... the interstices or cells formed by the different pairs of plates were filled with a solution of the muriate of ammonia [ammonium chloride] which here supplied the place of the moistened paper in the pile, but answered the purpose much better.

Mottelay emphasized the importance of this invention of Cruickshank stating that it was modified by Dr Wm. Babington (1756–1837) and that the great batteries of the Royal Institution were constructed on this principle. Furthermore, he says:

Cruickshank's plan was adopted in the construction of the powerful battery of 600 pairs, which Napoleon Bonaparte presented to the Ecole Polytechnique and upon which Gay-Lussac and Thenard made their important experiments during the year 1808.

Nicholson and Carlyle (1800) showed that electricity decomposed water to oxygen and hydrogen. Cruickshank showed that metals are deposited on the negative pole, while acids (anions) are deposited on the positive pole—the first example of electroplating. He also described how the electrolyte became increasingly acid at the anode and alkaline at the cathode.

Cruickshank also recommended that electrolytic deposition of the metal as a qualitative analysis test and described it as a test for copper [13]. This was how, for example, Davy finally purified strontium.

Conclusion

I hope you will be convinced that Wm. Cruickshank was a remarkable scientist, whose neglect has been a tragedy and whose recognition is overdue.

Acknowledgements This paper is part of a talk on William Cruickshank given at the 576th meeting of The United or Boro Hospitals Club.

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7. Quotes from Rollo's book—2nd edition; reprinted in *Philosoph Mag* 1798; 2: 240–250
8. Published originally in editions 1 and 2 of Rollo's book. Reprinted in two parts in *Nicholson's Journal* (1797; 1, 337–341 and 1799; 2: 406–411) and together in *Philosophical Mag* 1798; 2: 240–250
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Glossary

Acetite of lead	lead acetate
Acid of tartar	tartaric acid (a dicarboxylic acid)
Alum	aluminimum, potassium sulphate, $AlK(SO_4)_2$
Azotic gas	nitrogen
Barytes	$BaSO_4$
Carbonic acid gas (fixed air)	CO_2
Corrosive muriat of mercury	$HgCl_2$
Cream of tartar	potassium bitartrate
Hydrocarbonate gas	ether?
Lime (quick lime)	CaO
Lime water	$Ca(OH)_2$
Limestone	$CaCO_3$
Lithic acid	uric acid
Muriat of barytes	$BaCl_2$
Muriat of lead	$PbCl_2$
Muriat of potash	KCl
Muriat of soda	NaCl
Muriatic acid	HCl
Nitrat of mercury	$HgNO_3$
Nitrat of silver	$AgNO_3$
Nitrous acid	nitric acid
Nitrous gas	mixture of nitrogen oxides
Oxygenated muriat of potash	potassium chlorate
Oxymuriatic acid	chlorine
Phosphate of lime	calcium phosphate
Pyromucous acid	? fumaric acid