A practical handbook of medical chemistry.

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A

PRACTICAL HANDBOOK

OF

MEDICAL CHEMISTRY.

BY THE SAME AUTHOR.

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AN

INTRODUCTION TO CHEMISTRY;

WITH NUMEROUS ILLUSTRATIONS ON WOOD.

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A

PRACTICAL HANDBOOK

OF

MEDICAL CHEMISTRY.

BY

JOHN E. BOWMAN,

FELLOW OF THE CHEMICAL SOCIETY; AND DEMONSTRATOR OF CHEMISTRY IN KING'S COLLEGE, LONDON.

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PREFACE.

THE want which, as a teacher of Practical Chemistry in a Medical School, I have long felt, of a small manual containing instructions for the examination and analysis of urine, blood, and a few other of the more important animal products, both healthy and morbid, and comprising also directions for the detection of poisons in organic mixtures and in the tissues, was my chief inducement in undertaking to write the present little work.

In doing this, my endeavour has been to supply a book that will be found useful, not only to the Medical Student, but also to the Practitioner, to whom the value and importance of the applications of modern chemistry and microscopic analysis to his art, are becoming daily more and more apparent.

The writers to whom I have been chiefly indebted are Drs. Golding Bird, Owen Rees, Day, Franz Simon, Vogel, and Donné. My warm acknowledgments are also due

to my friend and colleague, Professor Miller, who, in addition to much other valuable assistance, kindly undertook to revise the proof-sheets during their passage through the press.

JOHN E. BOWMAN.

KING'S COLLEGE, LONDON,
April, 1850.

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THE symbols employed throughout the work are those now in common use among chemists. Substances in the solid state are represented by strong Roman type, as AsO_3, arsenious acid; liquids, and substances in solution, are printed in italics, as *HO*, water; and gases, in thin hair letters, as H, hydrogen, CO_2, carbonic acid. See Introduction to "Chemistry," pp. xviii.—xxiii.

MEDICAL CHEMISTRY.

PART I.

CHAPTER I.

HEALTHY URINE.

SECTION I.

1. HEALTHY human urine is an amber-coloured, watery fluid, holding in solution a great variety of substances, both organic and inorganic, and containing also in suspension a small quantity of mucus, derived from the bladder and urinary passages. The specific gravity (278) of the healthy secretion may be said to vary from 1003 to 1030, depending on the amount of solid and liquid food taken, the period of the day at which it is passed, and other circumstances, which tend to increase or diminish the proportion of solid matter contained in it. Thus the urine which is passed shortly after drinking much water or other fluid, commonly called *urina potus*, is usually pale in colour, and of low specific gravity, varying from 1003 to 1009; while, on the other hand, that which is secreted soon after the digestion of a full meal, commonly called *urina chyli*, has most commonly a high specific gravity, frequently 1030; the urine which is passed immediately after a night's rest, called *urina sanguinis*, may generally be considered to furnish a fair specimen of the average density of the whole urine, and will in most cases be found to have a specific gravity varying from 1015 to 1025. The average density of the whole urine passed by an individual in the twenty-four hours, is usually from 1015 to 1020; and the quantity passed during the same period varies from twenty to forty-eight or fifty ounces, holding in solution usually from 600 to 700 grains of solid matter (279).

2. While warm, urine has a slightly aromatic smell, which is not perceptible after cooling. The experiments of Dr. Bence Jones show that when passed shortly after eating, the urine is invariably alkaline to test paper, becoming gradually more and more acid, up to the time when the next meal is taken. When kept for some little time, it gradually becomes turbid, and deposits a sediment of earthy phosphates, previously held in solution by the slight excess of acid present (43). If the urine be kept for a still longer time it gradually putrifies, and, becoming more and more concentrated by spontaneous evaporation, deposits minute crystals of chloride of sodium, phosphates, and other salts, and eventually becomes covered with a greyish coloured mould.

3. Although chemists have not yet succeeded in insulating for examination all the ingredients of urine, nor even ascertained the general nature and character of several of the compounds which probably enter into its composition, still they have by their researches determined what appear to be the most important of its constituents; and it is to these only that the student need turn his attention, leaving the more problematical and obscure parts of the subject to be decided by the future labours of the physiological chemist.

4. The solid matters of the urine may be said to consist of the following—viz., *Urea; uric acid; hippuric acid; vesical mucus and epithelial debris; animal extractive; ammoniacal salts; fixed alkaline salts; and earthy salts.*

5. The student will do well to test a little of the healthy secretion, which should, for this purpose, be that passed immediately after a night's rest (1), for these several substances, in the manner described under each, in the following sections; and if he has leisure and opportunity, he may prepare specimens of urea, uric and hippuric acids, and some of the other constituents.

SECTION II.

Urea ($C_2H_4N_2O_2$).

6. This important ingredient of the urine, which appears to be the vehicle by which nearly the whole of the nitrogen of the exhausted tissues of the body is removed from the

system, is a solid crystalline substance, colourless when in a state of purity, and easily insulated from the other matters with which it is associated.

7. The presence of urea in the urine may be readily shown by concentrating a little of the secretion to about one-half or one-third its bulk, and mixing it with an equal quantity of pure nitric acid; when delicate crystalline rhomboidal plates of impure nitrate of urea ($C_2H_4N_2O_2$, HO,NO_5) will be found gradually to separate from the liquid (16).

8. Pure urea may be obtained from the urine, by first converting it into the oxalate ($C_2H_4N_2O_2,HO,C_2O_3$) (14), the crystals of which should be dissolved in hot water; after which the solution is treated with pounded chalk (CaO,CO_2) as long as effervescence is produced. The oxalic acid (C_2O_3) is thus removed from the urea, which latter remains in solution, while the insoluble oxalate of lime, (CaO,C_2O_3+2Aq), together with the excess of chalk employed, is precipitated.

$$\overbrace{C_2H_4N_2O_2,HO,C_2O_3}^{\text{Oxalate of urea.}}+\overbrace{CaO,CO_2}^{\text{Carb. lime.}}=\overbrace{CaO,C_2O_3}^{\text{Oxal. lime.}}+CO_2+$$

$$HO+\overbrace{C_2H_4N_2O_2}^{\text{Urea.}}.$$

The aqueous solution may then be purified by boiling with animal charcoal, and carefully evaporated at a gentle heat on a water bath, or under the receiver of the air-pump (Prac. Chem. 646), until the urea crystallizes.

9. The crystals of urea, which, when obtained by slow evaporation, are four-sided prisms, are soluble in about their own weight of cold water, and in a much smaller quantity of hot; from which latter the urea separates on cooling, in the form of beautiful silky needles. It is soluble in about 4.5 parts of cold alcohol, and in less than half that quantity of hot; in cold ether it is nearly insoluble. Its taste is saline and cooling, somewhat resembling that of nitre.

10. The proportion of urea present in healthy urine appears to vary from twelve to upwards of thirty parts in 1000, about fourteen or fifteen being the average.

11. An aqueous solution of urea may be kept, provided it is pure, for a considerable length of time, without under-

going chemical change; but if any albumen or mucus, or other fermentescible matter, is present, decomposition rapidly sets in, and in a short time the whole of the urea becomes transformed into carbonate of ammonia (NH_4O,CO_2), the elements of water being at the same time assimilated.

$$C_2H_4N_2O_2+4HO=2(NH_4O,CO_2).$$

In urine, this change speedily takes place, owing to the presence of mucus; the secretion thus acquiring, especially in warm weather, an alkaline reaction in the course of a few hours after being passed. Under the influence of the caustic alkalies also, urea becomes gradually converted into carbonate of ammonia.

12. When heated on platinum foil to about 250°, urea fuses without undergoing decomposition; but if the heat be increased much beyond that point, it is decomposed into ammonia (NH_3) and cyanate of ammonia (NH_4O,C_2NO), which volatilize, leaving a residue consisting chiefly of cyanuric acid ($3HO,Cy_3O_3$).

13. Urea, though its solution is neutral to test paper, has decidedly basic characters, combining with acids to form salts, some of which are crystalline. Of these, the two which are of the most practical importance, are the oxalate ($C_2H_4N_2O_2,HO,C_2O_3$) and the nitrate ($C_2H_4N_2O_2,HO,NO_5$), which, on account of their sparing solubility in water, supply a ready means of separating urea from the other matters co-existing in the urine.

14. *Oxalate of urea* ($C_2H_4N_2O_2,HO,C_2O_3$) may be prepared by concentrating urine on a water bath to about one-eighth its bulk, and filtering through muslin, in order to separate the insoluble sediment of phosphates and urates, which are gradually deposited during the evaporation. The liquid thus clarified, is mixed with about an equal bulk of a strong solution of oxalic acid in hot water, or the solid acid in powder may be added as long as the liquid, heated to about 190° or 200°, continues to dissolve it. The mixture, on cooling, deposits an abundant crop of crystals of oxalate of urea, mixed with a little of the excess of oxalic acid, and coloured brown by the adhering impurities. The crystals are then gently pressed between folds of filtering paper, washed with a small quantity of ice-cold water, and purified by recrystallization; the last traces of colouring

matter being removed, if necessary, by boiling the solution with animal charcoal.

15. The oxalate thus obtained is colourless, and in the form of tabular or prismatic crystals (Fig. 1), which are readily soluble in hot water, but only sparingly so in cold, twenty-five parts of which dissolve not more than one part of the salt.

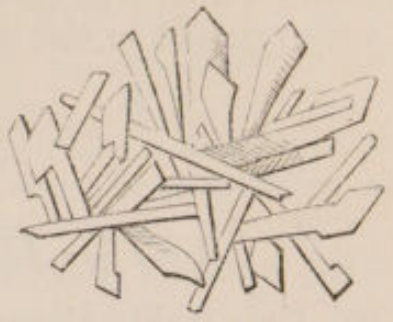

Fig. 1. Oxalate of urea.

16. *Nitrate of urea* ($C_2H_4N_2O_2,HO,NO_5$) may be obtained by adding strong colourless nitric acid, free from nitrous acid, to urine previously concentrated by evaporation to about one-third its bulk; the nitrate gradually separates in irregular rhomboidal plates (Fig. 2), more or less coloured and modified in form, by the impurities present. The crystals are washed with a little ice-cold water, then pressed between folds of filtering paper, and redissolved in lukewarm water; lastly, they are purified by recrystallization, and if necessary, the last traces of colouring matter may be removed by boiling the solution with animal charcoal.

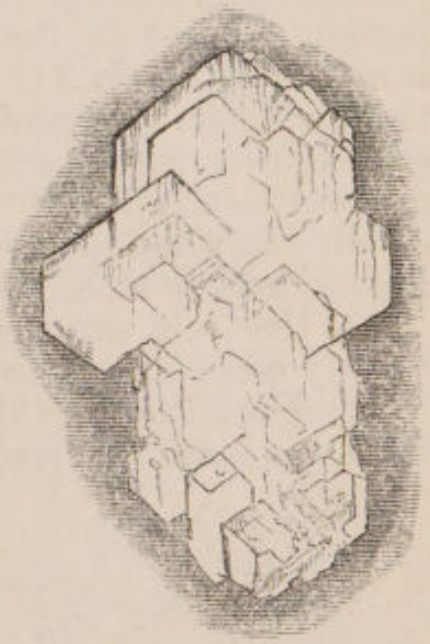

Fig. 2. Nitrate of urea.

17. Nitrate of urea is soluble in about eight times its weight of cold water, and in a much smaller quantity of hot. It is tolerably soluble also in alcohol, especially when warm; but almost insoluble in ether.

18. The formation of this crystalline compound on the addition of nitric acid is one of the most distinctive tests for the presence of urea which we possess. The experiment is made easily, and with great delicacy, under the microscope, by concentrating a drop or two of urine on a glass slide, and adding to it about an equal quantity of pure nitric acid; the nitrate will gradually crystallize in delicate rhomboidal plates (Fig. 2), the number and abun-

dance of which will furnish some indication of the quantity of urea present in the secretion (181).

SECTION III.

Uric (or Lithic) Acid ($C_{10}N_4H_4O_6$).

19. Uric acid, though usually present only in small quantity in human urine, appears to be one of the most important of its ingredients; and as the proportion varies considerably in many forms of disease, its determination, when in abnormal quantity, frequently affords much valuable assistance to the physician in diagnosis. The proportion present in the healthy secretion appears to vary from 0.3 to nearly 1.0 in 1000 parts, about 0.4 being the usual average. It probably exists for the most part in combination with ammonia, since, when uncombined, it requires nearly 15,000 times its weight of cold water to dissolve it, while the urate of ammonia ($NH_4O,C_{10}N_4H_4O_6$) is considerably more soluble (22).

20. Uric acid may be obtained by adding to urine, previously concentrated to about half its bulk, a few drops of hydrochloric acid (*HCl*), and allowing the mixture to stand for a few hours in a cool place. Minute reddish crystals of the acid gradually appear, having the forms shown in figure 3, stained with the colouring matters co-existing in the urine. These crystals may then be dissolved in moderately dilute potash, and from the solution thus obtained, the pure acid may be again precipitated in a crystalline and colourless state, by supersaturating it with hydrochloric acid.

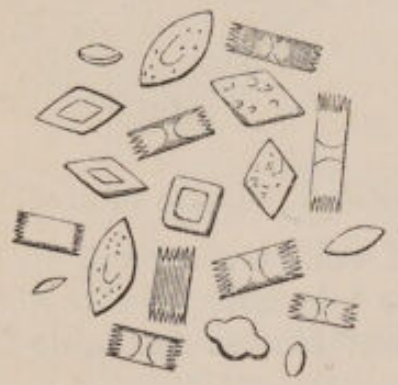

Fig. 3. Uric acid.

21. The crystalline forms in which uric acid is presented to us are very various (186), but they all appear to be modifications of the rhombic prism. Most of these crystals, when examined with the polarizing microscope, develope very beautiful colours; and their forms are frequently characteristic, and indicative of the peculiar circumstances under which they may have been deposited.

22. Uric acid requires, according to Liebig, about 15,000 times its weight of cold, and nearly 2000 times its weight of hot, water, to dissolve it, forming, in the latter, a solution which is feebly acid to test paper. It is insoluble in alcohol, and nearly so in dilute hydrochloric and sulphuric acids; it dissolves in the latter acid when concentrated, and is reprecipitated on the addition of water. It combines with bases, especially the alkalies and alkaline earths, forming salts (urates) which are for the most part insoluble, or very sparingly soluble in water. Of these the most soluble is the *urate of potash* ($KO,C_{10}N_4H_4O_6$), which dissolves in about 85 times its weight of hot water, and in a still smaller quantity if any free potash is present. On this account, uric acid dissolves with comparative facility in a solution of potash. *Urate of soda* ($NaO,C_{10}N_4H_4O_6$) requires for its solution 124 times its weight of hot water; and *urate of ammonia* ($NH_4O,C_{10}N_4H_4O_6$) 243 times its weight of hot, and about 1720 of cold, water, to effect its solution. The presence of a small quantity of chloride of sodium, such as is contained in the urine, renders water capable of dissolving nearly twice as much urate of ammonia as is taken up by pure water.

23. The action of nitric acid (NO_5) upon uric acid is highly characteristic, and furnishes, perhaps, the most delicate test of its presence which we possess. If a little of the acid, in the state of powder, is placed in a drop or two of tolerably strong nitric acid, in a watch glass or on a strip of glass, it will gradually dissolve; carbonic acid (CO_2) and nitrogen being given off with effervescence, and leaving behind a mixture of alloxan ($C_8N_2H_4O_{10}$), alloxantine ($C_4H_3N_2O_3$), and some other compounds. This may then be evaporated nearly to dryness at a gentle heat, when a red residue will be left, which, *when cold*, should be moistened with a drop or two of ammonia, or exposed to ammoniacal fumes, which will develop a beautiful purple colour, owing to the formation of murexide ($C_{12}N_5H_6O_8$). The same effect is produced when urate of ammonia, or any other urate, is similarly treated.

24. When heated before the blowpipe, uric acid is decomposed, emitting a disagreeable smell, resembling that of burnt feathers, mixed with that of hydrocyanic acid (840), which, together with carbonate of ammonia and some other compounds, is formed during the decomposition.

SECTION IV.

Hippuric acid ($HO,C_{18}NH_8O_5$).

25. A small quantity of hippuric acid appears to be generally present in healthy urine, and in certain forms of disease, especially in cases where a vegetable diet has been adopted, the quantity is found to increase considerably.

26. Hippuric acid may be prepared from fresh human urine, or still more readily from the urine of the herbivora, which usually contains it in much larger quantity than the human secretion. The urine is first evaporated at a gentle heat until it has the consistence of a syrup; it is then, after cooling, supersaturated with hydrochloric acid, which will dissolve the earthy salts, and cause at the same time a crystalline precipitate of impure hippuric acid mixed with colouring matters and other substances, which give it a more or less dark brown or reddish colour. The precipitate is then dissolved in a small quantity of hot water, from which it again crystallizes on cooling. The crystals, thus to a certain extent purified, are now dissolved in hot water, and a current of chlorine gas is passed through the hot solution, which has the effect of decomposing most of the colouring matter and other impurities, leaving the hippuric acid unaffected. The acid liquid is then neutralized with carbonate of soda, by which hippurate of soda ($NaO,C_{18}NH_8O_5$) is formed, the carbonic acid being given off with effervescence. The solution is now boiled with animal charcoal, in order to remove the last traces of colouring matter. The solution of hippurate of soda is filtered, and supersaturated with hydrochloric acid, which precipitates pure hippuric acid, in the form of minute tufts of needle-shaped crystals (Fig 4, *a* & *b*); these may be again dis-

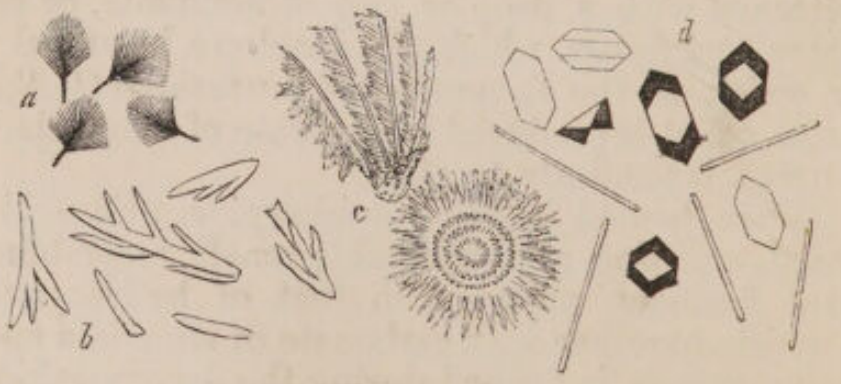

Fig. 4. Hippuric Acid.

solved in hot water, and allowed to cool gradually, when beautiful crystals (four-sided prisms) will be obtained, of considerable length, but so friable as to fall into powder under the slightest pressure.

27. Hippuric acid is very sparingly soluble in cold water, requiring about 400 times its weight of liquid to dissolve it; in hot water, however, it is readily soluble, and on cooling, crystallizes in beautiful silky tufts. It is very soluble in alcohol, and tolerably so in ether.

28. When mixed with uric acid, it may be separated from that substance by treating the mixture either with hot water or alcohol, in both of which uric acid is insoluble or nearly so (22). It may be distinguished from uric acid also, by its giving no purple colour when tested with nitric acid and ammonia (23), and by its different crystalline form (26, 29, 186).

29. When an alcoholic solution of hippuric acid is allowed to evaporate slowly, the crystalline residue which is left has usually some such appearance as that shown in figure 4, *c*. When deposited from a hot aqueous solution, the crystals have more the appearance shown at *d* in the figure.

30. When heated in a tube, it is converted chiefly into benzoic acid ($HO,C_{14}H_5O_3$) and benzoate of ammonia ($NH_4O,C_{14}H_5O_3$), which sublime, together with a red oily matter, which has a peculiar and characteristic smell, resembling that of the Tonka bean. Nitric acid converts hippuric acid into benzoic acid, as does also hot sulphuric acid, sulphurous acid (SO_2) being in the latter case evolved.

SECTION V.

Vesical Mucus and Epithelial Scales.

31. The small traces of mucus and epithelial debris, which are always present in urine, and which do not generally amount to more than from 0.1 to 0.3, in 1000 parts of the healthy secretion, are derived from the internal surface of the bladder and urinary passages. The quantity is so small as to be scarcely visible in healthy urine, until, after standing a short time, it has subsided, in the form of a thin cloud, to the bottom of the liquid. It may be

separated by passing the urine through a filter, on the sides of which it will be deposited in the form of a shining pellicle.

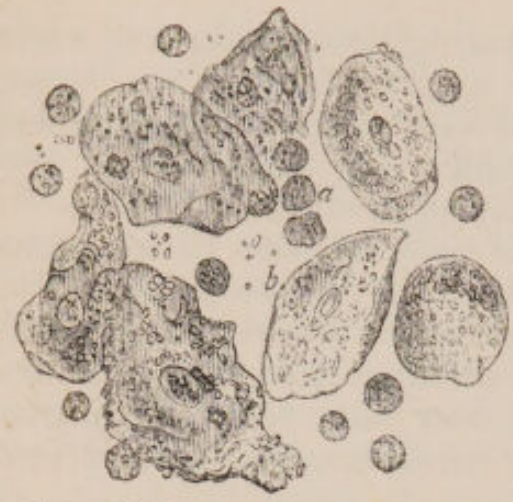

Fig. 5. Mucus Corpuscles and Scales of Epithelium. Magnified 200 Diameters.

32. When examined under the microscope, mucus is found to consist of minute granular corpuscles (Fig. 5, *a*) floating in the fluid, which are colourless, or nearly so, more or less round, and frequently oval in shape, and usually accompanied by epithelial scales. The mucus corpuscles dissolve when treated with strong nitric and acetic acids, forming a solution from which ferrocyanide of potassium throws down a white precipitate.

33. When treated with dilute acetic acid ($HO,C_4H_3O_3$), these corpuscles become more transparent, lose their granular appearance, and show in the interior one or more distinct nuclei (662). The corpuscles are unaffected, or nearly so, by the dilute mineral acids, but readily dissolve in a solution of potash, with the evolution of ammoniacal fumes. For the further characters of mucus, see paragraphs 99, 153, 210, 247, 660, &c.

34. The epithelial scales found in the urine, associated with mucus, and derived from the epithelial covering of the organs through which the secretion has passed, are usually more or less torn and broken (Fig. 5), but are occasionally met with uninjured, when they have the appearance shown at *b* in the figure.

SECTION VI.

Extractive Matter.

35. Under the name of *extractive matter* or *animal extract* may be included all the uncrystallizable organic matters found in the residue of evaporated urine, which are soluble either in water or alcohol, including two substances

which will probably be found to possess considerable physiological interest—viz., kreatine ($C_8N_3H_{11}O_6$) and kreatinine ($C_8N_3H_7O_2$),* and also the peculiar yellow colouring matter of the urine, of which indeed it appears mainly to consist; in other words, the extractive matter may be said to comprise all the combustible portion of the residue, with the exception of the urea, uric acid, vesical mucus, and ammoniacal salts.

36. These extractive matters, which in healthy urine usually amount to from seven to twelve parts in 1000, are sometimes divided into *spirit* or *alcohol extract*, including the portion soluble both in water and alcohol, which has also been called *osmazome;* and *water extract*, including that which is soluble in water and insoluble in alcohol. The real nature of these matters is still very imperfectly understood; and until we shall have obtained further insight into them and their connexion with the animal functions, the student may consider them as so much undefined matter, excreted from the body; without waiting to inquire whether lactic acid and other compounds, the presence of which may at present be considered as uncertain, are or are not contained in it.

SECTION VII.

Ammoniacal Salts.

37. These appear to consist chiefly of the muriate (NH_4Cl) and the urate ($NH_4O,C_{10}N_4H_4O_6$), though it is probable that some of the ammonia contained in the urine is in combination with the two other acids also present—viz., the sulphuric and phosphoric. The urate of ammonia, which has been already noticed (19), appears to be the form in which the uric acid present in the urine is for the most part held in solution, since the free acid requires for its solution a larger proportion of water than the secretion usually contains.

38. The presence of ammonia in urine is best shown by

* See Liebig's *Researches on the Chemistry of Food.*

adding a little caustic baryta (BaO,HO)* to the residue left after evaporating the liquid nearly to dryness at a gentle heat, when the odour of ammonia will be perceptible, and a rod moistened with dilute hydrochloric acid, held over it, will give rise to the characteristic white fumes of muriate of ammonia (Prac. Chem. 195). The proportion of ammonia contained in healthy urine appears to be very small; in some forms of disease, however, especially in certain kinds of fever, the quantity is found to increase considerably.

SECTION VIII.

Fixed Alkaline Salts.

39. The fixed salts present in the urine may be obtained by incinerating the evaporated residue, when a white ash will be left, consisting of a mixture of the alkaline and earthy salts; the former may then be separated from the latter by dissolving in water, in which the earthy salts are insoluble (43).

40. The alkaline salts, which in the healthy secretion usually amount to from thirteen to fourteen parts in 1000, consist of the sulphates of potash and soda (KO,SO_3) and (NaO,SO_3), chloride of sodium ($NaCl$), chloride of potassium (KCl), and phosphate of soda ($2NaO,HO,PO_5 + 24Aq$). The crystalline residue left after slowly evaporating a few drops on a piece of glass, usually has the appearance represented in Fig. 6. The crosslets (a) consist of chloride of

Fig. 6. Evaporated Residue of Healthy Urine.

* Baryta is here to be used in preference to potash, since the latter would cause the evolution of ammonia by its action upon the urea, which, in presence of the alkalies, is converted into carbonate of ammonia (11).

sodium; and the more plumose crystals (*b*) are probably phosphate of soda.

41. The presence of these several salts may be shown by adding to the aqueous solution of the ash, or to the urine, the following tests:—

(*a*) *Nitrate of silver* (AgO,NO_5) throws down a whitish precipitate, consisting of a mixture of chloride (AgCl) and phosphate ($3AgO,PO_5$) of silver. These may be separated from each other by warming the precipitate with a little nitric acid, when the phosphate will dissolve, leaving the insoluble CHLORIDE, which may then be tested with ammonia, in which it is readily soluble.

(*b*) The acid solution separated from the chloride (*a*) must now be cautiously neutralized with ammonia, which will throw down a pale yellow precipitate of PHOSPHATE ($3AgO,PO_5$), which may be again dissolved by adding a slight excess of nitric acid.

(*c*) *Chloride of barium* (*BaCl*), or *nitrate of baryta* (BaO,NO_5), throws down a white precipitate of sulphate of baryta (BaO,SO_3), mixed with phosphate of baryta ($2BaO,HO,PO_5$); which latter may be separated by digestion in nitric acid, which leaves the sulphate undissolved, proving the presence of SULPHURIC ACID. If the nitric acid solution of the phosphate be neutralized with ammonia, the phosphate of baryta is again precipitated.

(*d*) The absence of all bases except the alkalies, may be proved by testing the solution with hydrosulphate of ammonia (NH_4S,HS) and carbonate of soda (NaO,CO_2), neither of which will be found to cause any precipitate (Prac. Chem. 179).

(*e*) POTASH may be shown to be present by adding to a little of the strong solution about an equal quantity of bichloride of platinum ($PtCl_2$), which will cause a yellow precipitate of the double chloride of platinum and potassium ($KCl,PtCl_2$); and another portion may be tested with a solution of tartaric acid, which will throw down a white crystalline precipitate of the bitartrate ($KO,HO,C_8H_4O_{10}$).

(*f*) SODA may be identified by the behaviour of the saline solution with antimoniate of potash, with which it causes a white crystalline precipitate of antimoniate of soda (NaO,SbO_5); and by the mixture with bichloride of platinum (*e*) yielding, when slowly evaporated, yellow

needle-shaped crystals of the double chloride of sodium and platinum ($NaCl,PtCl_2$).

42. It is difficult to say in what exact state of combination these several bases and acids exist in the urine; but it is most probable that each base is divided among the several acids, and that a portion of each of the acids is combined with some of each of the fixed bases, and also of the ammonia (37, 40).

SECTION IX.

Earthy Salts.

43. The earthy salts, which form the insoluble portion of the ash, and which usually amount in healthy urine to about one part in 1000, consist of the phosphates of lime and magnesia, together with a small trace of silica. These earthy phosphates, which are insoluble in water, appear to be retained in solution in the urine by the small excess of acid (probably phosphoric) usually present in the healthy secretion, and may be immediately precipitated from it by supersaturating with ammonia. The precipitate thus formed consists of a mixture of PHOSPHATE OF LIME ($8CaO, 3PO_5$), and the DOUBLE PHOSPHATE OF AMMONIA AND MAGNESIA ($2MgO,NH_4O,PO_5+12Aq$), which is also called TRIPLE PHOSPHATE. If this precipitate be examined under the microscope, it will generally be found to consist of minute crystals of the triple phosphate, mixed with amorphous particles of phosphate of lime (Fig. 7).

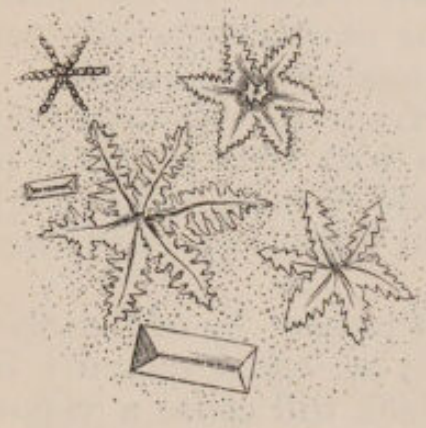

Fig. 7. Mixed Phosphates.

44. The crystalline form of the triple phosphate, as well as its chemical composition, depends upon the quantity of ammonia present in the liquid during its formation. When the urine is cautiously *neutralized* with the alkali, the

crystals are prismatic (Fig. 8), and in a few rare cases, penniform (Fig. 9), and appear to consist of (MgO,NH_4O,HO,PO_5); while, if a decided excess of ammonia be added,

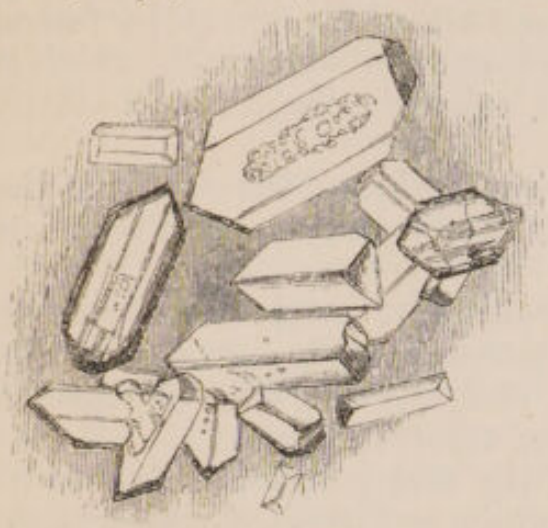

Fig. 8. Prismatic Crystals of Triple Phosphate.

Fig. 9. Penniform Crystals of Triple Phosphate.

the crystals are starlike and foliaceous, as shown in Fig. 10, and then consist of ($2MgO,NH_4O,PO_5+12Aq$). When the urine gradually becomes alkaline, owing to the spontaneous formation of ammonia from the urea (11), the triple phosphate is precipitated in the prismatic form, crystals of which are always to be detected in stale urine.

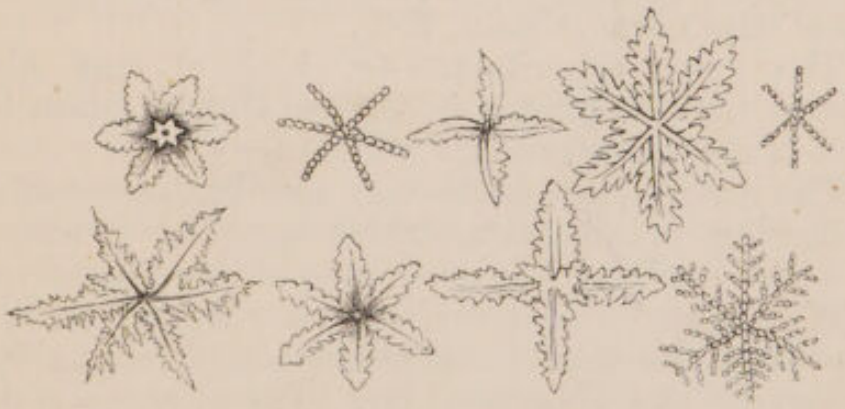

Fig. 10. Stellate Crystals of Triple Phosphate.

45. Both varieties of triple phosphate will be found to develope beautiful colours when examined with polarized light.

46. The presence of phosphoric acid, in combination with lime and magnesia, together with a trace of silica, in the insoluble portion of the ash, may be shown by digesting a

considerable quantity of the latter in dilute nitric acid, and filtering the solution from the insoluble residue. This insoluble portion, the amount of which is usually very small, may then be washed, and tested for SILICA, by fusion before the blowpipe with carbonate of soda, with which it will form, when pure, a clear colourless bead (Prac. Chem. 427).

47. The acid solution of the phosphates, filtered from the silica, may then be divided into two portions, and tested as follows :—

(*a*) To the first, add a few drops of a solution of nitrate of silver, and cautiously *neutralize* with ammonia. The yellow phosphate of silver ($3AgO,PO_5$) will be thrown down, proving the presence of PHOSPHORIC ACID.

(*b*) The second portion of the acid solution is now to be nearly neutralized with ammonia, and treated with oxalate of ammonia (NH_4O,C_2O_3) as long as it causes a precipitate, in order to separate the LIME, which is thrown down as oxalate (CaO,C_2O_3+2Aq).

(*c*) The mixture (*b*) is boiled, and filtered from the oxalate of lime; after which the clear solution is treated with a decided excess of ammonia, which will, in a short time, cause a deposition of the crystalline double phosphate of ammonia and MAGNESIA, thus proving the presence of the latter base (Prac. Chem. 206).

48. The same experiments (*a*, *b*, & *c*) may also be made upon the phosphates which are thrown down by the addition of ammonia to fresh urine.

49. The earthy phosphates may also be distinguished by the following peculiarities, which may be readily seen either with or without the assistance of the microscope.

(*a*) When present in excess, they may frequently be precipitated from the urine in an amorphous form, by boiling, thus behaving like albumen (139). The phosphatic deposit may be readily distinguished from the latter, by being soluble in a few drops of nitric acid, and in not being reprecipitated by any excess of that reagent (140).

(*b*) The earthy phosphates are readily soluble, without effervescence, in dilute acids, such as the hydrochloric, nitric, and acetic; and are reprecipitated by neutralizing the acid solution with ammonia; that of lime being amorphous, and the triple phosphate in a crystalline form, either prismatic or stellate (43).

(*c.*) They are insoluble in a solution of potash. The triple phosphate, when warmed with an excess of the alkali, gives off ammoniacal fumes, which may be detected by the smell, and by the white cloud formed, when a rod, moistened with dilute hydrochloric acid, is held at the mouth of the tube. $2\,MgO,NH_4O,PO_5+2(KO,HO)=2(MgO,HO)+NH_3+2KO,HO,PO_5$.

(*d.*) When heated before the blowpipe, phosphate of lime experiences little or no change, unless the heat be very intense, and continued for a long time, when it sometimes partially fuses. The triple phosphate, when heated, gives off ammonia and water; and the residual phosphate of magnesia ($2MgO,PO_5$) fuses considerably more readily than the phosphate of lime. When the two phosphates are mixed in about equal proportion, they resemble in composition the fusible calculus, and fuse with extreme facility before the blowpipe (392).

CHAPTER II.

QUANTITATIVE ANALYSIS OF HEALTHY URINE.

50. Counterpoise or weigh two Berlin porcelain evaporating basins, which, for the sake of distinction, may be marked A and B, each capable of holding about four ounces of water, and retain the counterpoises, marking them, in order to avoid confusion. Then weigh into each of the basins, 1000 grains of urine, and allow them to evaporate first on the water bath, and afterwards in a hot-water oven, or chloride of calcium bath (Prac. Chem. 647, 630), until they cease to lose weight when weighed at intervals of an hour or two. (While the evaporation is going on, the experiments described in paragraphs 59, 66, &c., may be proceeded with. The specific gravity also may be determined (278), and the action of the urine on test paper ascertained (277).) Then accurately weigh them, and if the weights of both residues agree with each other, the loss experienced during evaporation will represent the exact quantity of WATER contained in the urine. If the weights do not agree, it is probable

that the desiccation of at least one of the portions has been incomplete; in which case it is better to continue the heat a short time longer, until the results agree more closely.

51. The residue A may be first examined, retaining B for subsequent examination (62).

52. Warm the residue A with half an ounce or an ounce of alcohol of specific gravity about .833, stirring the mixture occasionally with a glass rod. Pour off the solution into another basin, and again warm the residue with a little more alcohol; fresh portions of which must be added until it ceases to dissolve anything more. Whether this is the case may be known by evaporating a drop of the clear liquid on platinum foil or a slip of glass, when, if anything has been dissolved, it will be left behind as a residue. The alcoholic solution, which will contain the whole of the urea, contaminated with extractive matter and other impurities, is now to be evaporated to dryness on a water bath, retaining the residue which proved insoluble in the alcohol for subsequent examination (57).

53. The residue, containing the urea, left after evaporating the alcoholic solution (52), is now to be dissolved in as small a quantity as possible of lukewarm water, and mixed with pounded oxalic acid (HO,C_2O_3+3Aq), which may be added as long as the liquid, heated to about 190° or 200°, continues to dissolve it (14). The urea is thus converted into the oxalate ($C_2N_2H_4O_2,HO,C_2O_3$), which, as the solution cools, crystallizes out, mixed probably with some of the excess of oxalic acid employed; together with extractive matters and other impurities, which give the crystals a more or less intense brown colour. The crystals are to be gently pressed between folds of filtering paper, and then washed in a basin with a very small quantity of cold distilled water, which may be poured off, and fresh water added to the crystals as long as it continues to become decidedly coloured; by which means most of the soluble salts and other foreign matters are removed.

54. The washings are now to be concentrated to a small bulk by evaporation on a water bath, and left to cool, when a fresh crop of crystals will gradually separate. Care must be taken that an excess of oxalic acid is present in the liquid separated from the crystals, which may be known by its reddening litmus paper; if this is found on trial not to be the case, a little more of the pounded oxalic acid must be

added to the solution, as otherwise, some of the urea, which, when uncombined, is very soluble in water, might escape separation.

55. When the whole of the oxalate of urea has been separated by successive crystallizations from the liquid, it must be gently pressed between folds of filtering paper, and dissolved in warm water; after which the solution is to be digested for a few hours, at a temperature of about 100° F. with pounded carbonate of lime, stirring the mixture from time to time with a glass rod, as long as any effervescence is produced. The oxalate is thus decomposed in the following manner:—

Oxalate of urea. Oxalate of lime.

$$\overbrace{C_2N_2H_4O_2,HO,C_2O_3}+CaO,CO_2=\overbrace{CaO,C_2O_3}+CO_2+HO$$

Urea.

$$+\overbrace{C_2N_2H_4O_2}.$$

56. The urea, which being soluble, remains in solution, is to be separated by filtration from the insoluble oxalate and carbonate of lime, and carefully evaporated to dryness either on a water bath or in vacuo over sulphuric acid (Prac. Chem. 646). Its weight will then represent the proportion of UREA in 1000 grains of the specimen of urine under examination.

57. The portion of the residue which proved insoluble in the alcohol (52), containing the uric acid, vesical mucus, the extractive matter soluble in water but insoluble in alcohol, the earthy salts, and most of the other saline matter, is now to be well stirred with successive small portions of warm water, which leaves undissolved the uric acid, mucus, and earthy salts. The insoluble matter is to be placed in a platinum or porcelain crucible, previously weighed or counterpoised, and then carefully dried on a water bath, or in a hot-water oven, and weighed. The weight having been noted, the dry residue is to be ignited in the crucible (Prac. Chem. 648), until the incombustible ash becomes white, or very nearly so; when the crucible with its contents is to be again weighed. The difference between this weight, and that of the dry residue previous to ignition, gives the amount of combustible matter, consisting of URIC ACID and VESICAL MUCUS; while that of the ash represents the EARTHY PHOSPHATES AND SILICA.

58. The portion of urine A will now have given us the weight of, 1. The Water; 2. Urea; 3. Uric acid and vesical mucus; and 4. Earthy phosphates and silica.

59. For the purpose of ascertaining the respective weights of the uric acid and vesical mucus, 2000 grains of the fresh urine may be concentrated by evaporation to about half its bulk, and mixed with twenty or thirty drops of hydrochloric acid. In the course of twenty-four hours, the whole of the uric acid will have been set free by the hydrochloric acid, and being insoluble (22), will be deposited in the form of minute crystals on the sides and bottom of the glass. These are to be collected on a weighed filter, and, after being washed with a little alcohol, dried in a hot-water oven or on a water bath. The weight of this acid, divided by two, (since it is derived from 2000 grains of urine) will represent the URIC ACID contained in 1000 grains of the secretion; and having already determined the quantity of uric acid and VESICAL MUCUS together (57), the weight of the latter is known by deducting from the combined weights that of the uric acid.

60. The proportion of uric acid and mucus may also be determined by evaporating to dryness 1000 grains of the urine, previously filtered from the mucus, and washing the residue first with dilute hydrochloric acid, (containing one part of acid to eight or ten of water,) and afterwards with a little alcohol. We thus dissolve out everything but the uric acid, which, after being washed with cold water, may be dried and weighed.

61. If it is required to determine the respective proportions of earthy phosphates and silica, in the residue of earthy salts (57), which, however, is seldom necessary, since the quantity of silica is always very small, it may be done in the following manner:—Moisten the residue with hydrochloric acid, and evaporate to dryness; then digest it, with the aid of a gentle heat, in dilute hydrochloric acid, which will dissolve out the phosphates, leaving the SILICA perfectly insoluble (Prac. Chem. 426). The weight of the latter is then ascertained, and deducted from the gross weight of the earthy salts (57), when the difference will represent that of the EARTHY PHOSPHATES; or the phosphates may be precipitated from the hydrochloric acid solution by supersaturating it with ammonia, filtered, ignited, and weighed.

62. We have now to operate upon the residue left after the evaporation of the second portion of urine marked B (50), for the purpose of determining the weights of—1. the animal extractive and ammoniacal salts; and 2. the fixed alkaline salts.

63. The dry residue, after being accurately weighed, is to be incinerated in a platinum or porcelain crucible, until the whole of the blackness (carbon) has disappeared, after which the weight of the ash is to be noted. The loss experienced during ignition being due to the combustion of the organic matters and the volatilization of the ammoniacal salts; and as we have already ascertained the weight of the urea, uric acid, and vesical mucus, we have only to deduct from the whole amount of loss the combined weights of those three substances, in order to determine the quantity of the ANIMAL EXTRACTIVE AND AMMONIACAL SALTS.

64. The ash obtained by ignition contains the whole of the inorganic matter, or, in other words, the fixed alkaline and earthy salts contained in the urine. By deducting from this the weight of the earthy salts already determined (57), we obtain the proportion of FIXED ALKALINE SALTS.

65. We shall thus have determined the proportion of the

Water,
Urea,
Uric acid,
Vesical mucus,
Animal extractive and ammoniacal salts,
Fixed alkaline salts,
Earthy phosphates,
Silica,

which, when added together, ought to make up a fraction less than 1000 grains, some slight loss being unavoidable during the course of the analysis.

Quantitative determination of the inorganic salts.

66. When it is required to estimate the proportion of the several inorganic salts, whether earthy or alkaline, which are contained in the urine, the following plan will be found simple and convenient; or if the estimation of one or two only of the ingredients is required, some modification of it may be adopted.

67. Weigh out two portions of the inorganic ash (57) in

powder, one of 50 grains, and the other 10 grains. The first (50 grains) we will call A, and the second (10 grains) B. The portion B will serve for the estimation of the chlorine (69), and the portion A for that of the other saline ingredients (68).

68. Digest the portion A in about four ounces of hot water; filter, and wash the insoluble residue with a little more hot water, in order to dissolve out the whole of the soluble matter. We thus divide A into two parts, both of which must be retained for subsequent examination: 1st, the insoluble or earthy salts, which we will call C (70); and 2nd, the soluble or fixed alkaline salts, which portion we will call D (75).

69. While the washing and filtering of A is going on, digest the portion B, consisting of ten grains of the ash, in about two ounces of hot water, and wash the insoluble residue on a filter until the whole of the soluble matter is dissolved out from the residue of earthy salts, which latter may be thrown away. Acidify the aqueous solution thus obtained with a little nitric acid, and add a solution of nitrate of silver as long as it causes any precipitate. The chloride of silver (AgCl) thus precipitated is now, after boiling, filtered, dried, and weighed, and the chlorine calculated as follows:—

Atc. wt. of chloride of silver.		Atc. wt. of chlorine.		Weight of chloride obtained.		Wt. of chlorine in 10 grs. of the ash.
144	:	36	::	a	:	x

which, when multiplied by five ($10 \times 5 = 50$), will represent the quantity of CHLORINE in fifty grains of the ash. The liquid filtered from the chloride of silver need not be retained.

70. The insoluble residue C (68) may now be examined, for the purpose of estimating the quantity of lime, magnesia, and phosphoric acid, contained in the earthy phosphates. It is to be dissolved in a little dilute nitric or hydrochloric acid, and filtered from any carbonaceous or siliceous matter that may resist the action of the acid. The acid solution of the earthy phosphates is now supersaturated with ammonia, which will throw them down in the form of a white precipitate. This precipitate is to be washed on a filter, dried, and, after gentle ignition in a platinum or porcelain crucible, weighed. This weight will, of course, represent

the quantity of EARTHY PHOSPHATES in fifty grains of the ash.

71. The weight of the earthy phosphates having been taken (70), they are to be re-dissolved in dilute nitric or hydrochloric acid, again thrown down by neutralizing the acid solution with ammonia, and once more dissolved by adding an excess of acetic acid; the acetic acid being here used as the solvent, because the oxalate of lime, which is about to be precipitated, is insoluble in an excess of acetic acid, but soluble in most of the other acids (169, 170).

72. Oxalate of ammonia is now added as long as it causes a precipitate; and the oxalate of lime (CaO,C_2O_3+2Aq) thus thrown down, is filtered, washed, dried, gently ignited, by which it is converted into carbonate (CaO,CO_2), and weighed (171). The weight of LIME contained in the fifty grains of ash may then be calculated as follows:—

Atc. wt. of carbonate of lime.		Atc. wt. of lime.		Wt. of carbonate of lime obtained.		Wt. of lime contained in 50 grs. of ash.
50	:	28	::	a	:	x

73. The solution filtered from the oxalate of lime (72), is now again strongly supersaturated with ammonia, which will throw down the magnesia in the form of the double phosphate of ammonia and magnesia ($2MgO,NH_4O,PO_5+12Aq$). The mixture is well agitated, and allowed to stand some hours, in order to ensure the separation of the whole of the magnesian salt; after which the precipitate is washed with a little dilute ammonia, in which it is less soluble than in pure water, dried, ignited, (by which it is converted into phosphate of magnesia ($2MgO,PO_5$),) and weighed. From the weight thus obtained, that of the MAGNESIA in fifty grains of the ash may be calculated as follows:—

Atc. wt. of phosphate of magnesia ($2MgO,PO_5$).		Atc. wt. of magnesia.		Wt. of phosphate obtained.		Wt. of magnesia in 50 grs. of ash.
112	:	40*	::	a	:	x

74. The weight of the PHOSPHORIC ACID contained in the earthy phosphates may now be estimated by adding together that of the lime and magnesia, and deducting the

* $40=20\times2$; because each equivalent of the phosphate ($2\,MgO,PO_5$) contains two equivalents of magnesia.

sum of them from the entire weight of the earthy phosphates, obtained in paragraph 70.

75. The soluble portion of the ash, D, containing the alkaline salts, and which was dissolved out from the earthy salts (68), must now be examined. The solution is acidified with a little nitric acid, and then treated with a solution of chloride of barium as long as any precipitate is produced. The sulphuric acid of the ash is thus thrown down as sulphate of baryta (BaO,SO_3), which is to be filtered, washed, dried, ignited, and weighed. From the weight of the sulphate of baryta thus obtained, that of the SULPHURIC ACID, in fifty grains of the ash, is calculated as follows:—

Atc. wt. of sulphate of baryta.		Atc. wt. of sulphuric acid.		Wt. of sulphate of baryta obtained.		Wt. of sulphuric acid in 50 grs. of the ash.
117	:	40	::	a	:	x

76. The acid solution, filtered from the sulphate of baryta (75), must now be concentrated to about half or one third its bulk, and then neutralized or slightly supersaturated with ammonia; a little more of the solution of chloride of barium being added, to ensure the precipitation of the whole of the phosphoric acid. This will throw down the phosphoric acid previously in combination with the alkaline bases, in the form of phosphate of baryta ($2BaO,HO,PO_5$), which is to be washed with a small quantity of water, dried, ignited, and weighed. From the weight of the phosphate of baryta thus obtained, that of the phosphoric acid in the alkaline portion of the fifty grains of ash, may then be calculated as follows:—

Atc. wt. of phosphate of baryta.		Atc. wt. of phosphoric acid.		Wt. of phosphate of baryta obtained.		Wt. of phosphoric acid in the alkaline salts of 50 grs. of the ash.
226	:	72	:	a	::	x

77. It may be mentioned that the results afforded by this method of estimating the phosphoric acid in the alkaline salts, are not perfectly accurate, the composition of the phosphate of baryta not being always precisely the same, and that salt being also to a slight extent soluble in water, especially when ammoniacal salts are present in the solution. It will, however, be found sufficiently accurate for all practical purposes.

78. The excess of baryta introduced in the chloride of

barium (75), is now to be removed from the solution. This is done by boiling the solution with a mixture of caustic ammonia and carbonate of ammonia, as long as any precipitate is produced. When it is supposed that the whole of the baryta has been precipitated, a drop or two of the clear liquid should be taken, and tested with a solution of sulphate of soda; if this causes no precipitate, it may be safely concluded that the whole of the baryta has been precipitated as carbonate. The mixture is then filtered from the precipitated carbonate of baryta; the filtered liquid is evaporated to dryness, and the residue gently ignited, in order to expel the ammoniacal salts.

79. The residue after ignition, consisting merely of the chlorides of potassium and of sodium, is now to be weighed. It is then dissolved in a small quantity of water, mixed with a solution of bichloride of platinum, and the mixture is evaporated to dryness, or nearly so, on a water bath. The residue is treated with successive small portions of alcohol, which will dissolve out the excess of the bichloride of platinum, together with the chloride of sodium; leaving undissolved the double chloride of platinum and potassium, ($KCl,PtCl_2$). The latter is to be dried in a weighed filter, at a temperature of 212°, and weighed. From the weight of the double chloride thus obtained, we may then calculate that of the POTASH equivalent to it, as follows:—

Atc. wt. of the double chloride of platinum and potassium.		Atc. wt. of potash.		Wt. of the double chloride obtained.		Wt. of potash in 50 grs. of the ash.
247	:	48	::	a	:	x

80. From the weight of potash thus obtained, we are enabled to ascertain how much of the mixed chlorides (79) was chloride of potassium; and the difference between the latter and the gross weight will of course represent the quantity of chloride of sodium. The weight of chloride of potassium equivalent to the potash, is for this purpose calculated as follows:—

Atc. wt. of potash.		Atc. wt. of chloride of potassium.		Wt. of potash obtained.		Wt. of chloride of potassium contained in the mixed chlorides.
48	:	76	::	a	:	x

81. The weight of chloride of potassium thus calculated, is then deducted from the weight of the mixed chlorides

(79), and the difference will represent the weight of chloride of sodium; thus :—

Weight of mixed chlorides	
Deduct weight of chloride of potassium	
Weight of chloride of sodium	

82. The *whole* of the soda, however, does not exist in the urine as chloride of sodium, a portion of it being in combination with phosphoric, and perhaps also with some of the other acids present. We have therefore to calculate from the quantity of chlorine obtained in a former experiment (69), how much of the chloride of sodium obtained in paragraph 81, existed as such in the urine. This is done as follows :—

Atc. wt. of chlorine.		Atc. wt. of chloride of sodium.		Wt. of chlorine in 50 grs. of ash.		Wt. of chloride of sodium in 50 grs. of ash.
36	:	60	::	a	:	x

83. The quantity of CHLORIDE OF SODIUM thus calculated, is deducted from the whole weight of chloride of sodium previously obtained (81), and the difference will represent the amount of chloride of sodium equivalent to the SODA, which in the urine was combined with phosphoric or other acids; thus :—

Atc. wt. of chloride of sodium.		Atc. wt. of soda.		Difference between the two amounts of chloride of sodium.		Soda existing as such in 50 grs. of the ash.
60	:	32	::	a	:	x

84. All the quantities obtained in the foregoing experiments (67 to 83), represent the amounts of the several saline ingredients contained in fifty grains of the ash: as, however, the organic ingredients were estimated as contained in 1000 grains of urine (65), the proportion of the inorganic constituents should also be reduced to the same scale. This may be done in the case of each constituent by the following calculation :—

50 :	Quantity of inorganic matter in 1000 grs. of urine.	::	Wt. of each constituent obtained from 50 grs. of the ash.	:	Wt. of that constituent contained in 1000 grs. of urine.

CHAPTER III.

AVERAGE COMPOSITION OF HEALTHY URINE.

85. The following analyses of healthy human urine will serve to give some idea of its average composition. Although the amount of the several constituents will be seen to differ considerably from each other, it will be found that these differences are not really quite so great as they at first sight appear, being in a great measure owing to variations in the relative proportions of water and solid ingredients (1).

Analysis I. (*Berzelius.*)

Water	933.00		
Urea	30.10		Solid matter 67.00.
Uric acid	1.00		
Lactic acid, lactate of ammonia, and extractive matters	17.14		
Mucus	0.32		
Sulphate of potash	3.71	Fixed salts 15.29.	
Sulphate of soda	3.16		
Phosphate of soda	2.94		
Biphosphate of ammonia	1.65		
Chloride of sodium	4.45		
Muriate of ammonia	1.50		
Phosphates of lime and magnesia	1.00		
Silica	0.03		
	1000.00		

Analysis II. (*Simon.*)

Specific gravity, 1012.

Water	956.000		
Urea	14.578		Solid matter 44.00.
Uric acid	0.710		
Extractive matters and ammoniacal salts	12·940		
Chloride of sodium	7.280	Fixed salts 13.77.	
Sulphate of potash	3.508		
Phosphate of soda	2.330		
Phosphates of lime and magnesia	0.654		
Silica	a trace		
	998.000		

Analysis III. (*Dr. Miller.*)

Specific gravity, 1020.

Water	956.8000		
Urea	14.2300		
Uric acid	0.3700		
Alcohol extractive	12.5270	29.822 Organic matters.	
Water extractive	1.6050		
Vesical mucus	0.1650		
Muriate of ammonia	0.9154		42.98 Solid matters.
Chloride of sodium	7.2195		
Phosphoric acid	2.1189		
Sulphuric acid	1.7020		
Lime	0.2101	13.158 Fixed salts.	
Magnesia	0.1198		
Potash	1.9260		
Soda	0.0536		
	999.9623		

Analysis IV. (*Marchand.*)

Water	933.199	
Urea	32.675	
Uric acid	1.065	
Lactic acid	1.521	
Extractive matters	11.151	
Mucus	0.283	
Sulphate of potash	3.587	66.8 Solid matters.
Phosphate of soda	3.056	
Sulphate of soda	3.213	
Biphosphate of ammonia	1.552	
Chloride of sodium	4.218	
Muriate of ammonia	1.652	
Phosphates of lime and magnesia	1.210	
Lactates	1.618	
	1000.000	

Analysis V. (*Lehmann.*)

Water	937.682	
Urea	31.450	
Uric acid	1.021	
Lactic acid	1.496	
Water and alcohol extractives	10.680	
Lactates	1.897	62.318 Solid matters.
Chlorides of sodium and ammonium	3.646	
Alkaline sulphates	7.314	
Phosphate of soda	3.765	
Phosphates of lime and magnesia	1.132	
Mucus	0.112	
	1000.195	

Analysis VI. (*Becquerel.*)

Showing the comparative composition of male and female urine.

	Mean Composition of the urine of four healthy men.	Ditto of four healthy women.	General mean.
Specific gravity	1018.9	1015.12	1017.01
Water	968.815	975.052	971.935
Solid constituents	31.185	24.948	28.066
Urea	13.838	10.366	12.102
Uric acid	0.391	0.406	0.398
Other organic matters	9.261	8.033	8.647
Fixed salts	7.695	6.143	6.919
Consisting of—			
Chlorine			0.502
Sulphuric acid			0.855
Phosphoric acid			0.317
Potash			1.300
Soda, lime, and magnesia			3.944

CHAPTER IV.

MORBID URINE.

86. The urine passed during a diseased state of the system, is almost invariably more or less altered in its composition, and frequently presents physical peculiarities, as of colour, opacity, &c., which are at once apparent on the most cursory examination. The variations which are found to occur in the chemical composition of morbid urine may be divided into two classes—viz.,

1st. Those in which no abnormal ingredient is present, but in which one or more of the normal constituents is present either in greater or less proportion than is found in healthy urine, or is altogether absent.

2nd. Those in which one or more abnormal ingredients are present, which are not found in the healthy secretion.

I. *Urine containing no abnormal ingredient, but in which an excess or deficiency of one or more of its normal constituents is present.*

SECTION I.

Urine containing Urea in abnormal quantity.

87. Urine containing an excess of urea, is chiefly characterized by its high specific gravity, in which respect it resembles that secreted by diabetic patients (116). If the urea be present in large excess, it deposits irregular rhomboidal crystals of the nitrate ($C_2N_2H_4O_2$,HO,NO_5), when the urine, either in its natural state, or especially when slightly concentrated, is mixed with an equal quantity of nitric acid (181). The proportion of urea present in healthy urine is usually about fourteen or fifteen parts in 1000 (10); while in disease it often amounts to thirty parts, or even more.

SECTION II.

Urine containing uric (or lithic) acid in abnormal quantity.

88. When urine contains an excess of uric acid, it has usually rather a higher colour than the healthy secretion, either deep amber or reddish brown. Its specific gravity is seldom much higher than 1020 or 1025, unless an excess of urea is also present, which is not unfrequently the case. It generally has a slightly acid reaction to test paper; and if the uric acid is present in any considerable excess, it is partially deposited as the urine cools, in the form of a crystalline sediment, usually of a more or less decided red colour, and frequently mixed with urate of ammonia, mucus, and other matters. The crystalline forms in which uric acid is found in the urine, are represented in figure 30, paragraph 186. This deposition of uric acid is greatly accelerated by the addition of a few drops of nitric or hydrochloric acid to the urine (20).

89. The urine of infants and young children not unfrequently deposits lozenge-shaped crystals of nearly pure uric acid, containing only a trace of yellow colouring matter. It rarely happens that uric acid is deposited in the solid state previous to emission, being held in solution in the warm liquid, and gradually separating in the form of a sediment, as the secretion cools (186).

90. The quantity of uric acid, which, in the healthy secretion, is seldom more than from 0.3 to 1.0 in 1000 parts, varies in morbid urine from a scarcely perceptible trace, to upwards of two parts in 1000.

SECTION III.

Urine containing an excess of urate (or lithate) of ammonia.

91. Urine containing an excess of urate of ammonia varies very much in colour and appearance, being sometimes pale and of low specific gravity, but more frequently high coloured, dense, and turbid. It is most commonly slightly acid, but is also met with neutral and even alkaline.

Fig. 11. Urate of ammonia.

The urate of ammonia is gradually deposited as the urine cools, in the form of an amorphous precipitate, which, with a high magnifying power, appears to consist of minute rounded particles, occasionally adhering together, and forming irregular linear masses (Fig. 11); frequently mixed with microscopic crystals of uric acid; and occasionally, when the secretion is neutral or at all alkaline, with the earthy phosphates (106).

92. Urate of ammonia has been met with in a few rare cases, in the form of globular masses of a larger size, and pierced with spicular crystals, probably of superurate of ammonia (Fig. 12). Like the other varieties of urate of ammonia deposit, it is usually found mixed with crystals of uric acid.

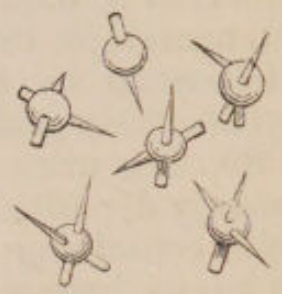

Fig. 12. Urate of ammonia.

93. Urate of ammonia constitutes one of the most common of the urinary deposits. The colour of the sediment is found to vary considerably, being met with of all shades, from pale fawn colour to reddish purple or pink, the latter colours being due to the admixture of purpurine, which is very frequently found associated with the urates (104, 217). Traces of the urates of soda, lime, and magnesia are not unfrequently found associated with urate of ammonia deposits.

94. A deposit of urate of ammonia readily dissolves when the urine containing it is gently warmed; and is again precipitated as the liquid cools. If, however, as is often the case, it contains also an admixture of free uric acid or earthy phosphates, the deposit will not wholly dissolve on the application of heat, those substances being nearly as insoluble in hot as in cold water. The presence of purpurine (104, 217) usually renders the urate less easily soluble when warmed.

95. When a deposit of urate of ammonia is treated with a little dilute hydrochloric or acetic acid, it is decomposed;

and minute crystals of uric acid shortly appear, which may be readily distinguished under the microscope (194).

SECTION IV.

Urine containing Urate (or Lithate) of Soda ($NaO,C_{10}N_4H_4O_6$).

96. Urate of soda is not unfrequently met with in the urine of patients taking medicinally the carbonate or other salts of soda. It may generally be recognised without difficulty under the microscope, usually forming minute globular and sometimes granulated aggregations, with occasionally irregular and curved protuberances, as shown in figure 13.

Fig. 13. Urate of soda.

97. It resembles the urate of ammonia in being soluble in hot water (22, 192), and also in most of its chemical characters; giving the same purple-coloured residue when tested with nitric acid and ammonia (23). It also yields crystals of uric acid, when treated with dilute hydrochloric acid (194). When warmed with potash, however, it does not of course give off ammoniacal fumes (377); and by this, and more especially by its behaviour before the blowpipe (202), and by its microscopic appearance, it may be readily distinguished from the ammoniacal salt. The two salts are frequently found occurring together in the same deposit.

SECTION V.

Urine containing an excess of Hippuric Acid.

98. There is but little that can be said to be characteristic in the appearance of urine in which an excess of hippuric acid is present. It is most commonly either neutral or slightly acid to test paper, but occasionally alkaline; and is in most cases pale and whey-like, and of low specific gravity. The mode of its detection will be found described in paragraphs 206, &c.

SECTION VI.

Urine containing an excess of Mucus.

99. Mucous urine is most commonly very similar in colour to the healthy secretion. It deposits a viscid, tenacious sediment, usually of a dirty yellowish colour, consisting chiefly of mucus mixed with epithelium (328); which, when agitated, does not mix again uniformly with the fluid, but coheres together in tenacious, ropy masses, entangling and retaining numerous bubbles of air.

100. Urine containing an excess of mucus is generally neutral or slightly acid when passed, unless it has been retained some time in the bladder, when it is not unfrequently alkaline; and when this is not the case, it very speedily becomes so, owing to the rapid conversion of the urea into carbonate of ammonia under the influence of the mucus (11). This change takes place first in the portion of the fluid which is in contact with the mucous sediment: this may frequently be seen in specimens of slightly acid urine, the upper portions of which redden litmus paper; but if the lower part more immediately in contact with the mucus be tested, it will be found to restore the original blue colour.

101. Mucous urine differs from that containing pus, in the ropy and tenacious character of the deposit; and also in not giving any sensible indication of albumen when tested with heat and nitric acid (254), unless the albumen be derived from some other independent source, which is sometimes the case (255). Minute traces of albumen, indeed, are present in the undiluted mucous fluid, but the quantity is so small, that when mixed with urine it is incapable of being detected (663).

102. The mucous deposit is frequently found mixed with a considerable quantity of earthy phosphates or urates, in which case it is more liable to be mistaken for pus. The true nature of such a mixed deposit is, however, readily distinguished by microscopic examination, which should always be had recourse to in such cases (211, 156, 328).

SECTION VII.

Urine containing an excess of Extractive Matters and Ammoniacal Salts.

103. Urine containing extractive matters in excess is usually more highly coloured than the natural secretion, a large proportion of what is included under the title of extractive matter consisting apparently, in most cases, of the peculiar colouring matters of the urine. When boiled, and subsequently mixed with a little hydrochloric acid, such urine becomes of a more or less decided red colour; and on cooling, usually deposits a quantity of brownish or bluish black sediment, which is readily soluble in alcohol.

104. It is not unfrequently the case that the peculiar red colouring matter called purpurine is present in considerable quantity in certain forms of morbid urine. This, when a deposit of urate of ammonia is also present, is precipitated with the urate, giving the sediment a pink or red colour (217). When no deposit of urate exists, the purpurine remains in solution, giving the urine a more or less bloody appearance, which may sometimes lead to the suspicion that blood is present. For the methods of identifying purpurine, see paragraphs 216 to 221.

SECTION VIII.

Urine containing an abnormal proportion of fixed Alkaline Salts.

105. When these salts are present in excess they tend to raise the specific gravity of the secretion. The quantity of soluble saline matter may be readily estimated in the mass, by incinerating the dry residue left after evaporating a known weight of the urine, and treating the ash with water, which will dissolve out the alkaline salts, leaving the earthy phosphates and silica undissolved. The aqueous solution is then evaporated to dryness, ignited, and weighed. The individual proportion of the several salts, which is sometimes a point of considerable interest, may be determined in the manner described in paragraphs 66 to 84.

SECTION IX.

Urine containing the Earthy Phosphates in abnormal quantity.

106. The physical characters of urine containing an excess of earthy phosphates vary considerably. The colour is most commonly pale, and the specific gravity rather low, but it is also occasionally dark, and of high specific gravity, especially when urea is present in large quantity (87, 301). It is generally slightly acid when passed, but shortly becomes neutral or alkaline (43), when the phosphates are precipitated, often in large quantity, in the form of a crystalline sediment, the colour of which varies from white and grey to a dirty yellow or reddish brown. When white or grey, the sediment will probably be found to consist chiefly of phosphates mixed with mucus; when yellowish or red, it will probably be found to contain, in addition, a certain amount of uric acid, or urate of ammonia, most commonly the latter.

107. It must be borne in mind that the spontaneous occurrence of a precipitate of earthy phosphates is not of itself a proof that they are present in excess; nor, on the other hand, is the non-occurrence of a deposit a proof that a small quantity only is present. When the urine is acid, as in health, they may be retained in solution in considerable quantity, without forming any solid sediment; while, if the secretion is neutral or alkaline, a comparatively small amount of earthy phosphates may be precipitated in the form of a deposit.

108. When examined with the microscope, deposits of the earthy phosphates will frequently be found to contain both the crystalline triple phosphate (MgO,NH_4O,HO,PO_5), and also phosphate of lime, in the form of an amorphous powder, or in minute, irregular, rounded particles (43, 44).

109. The quantity of earthy phosphates, which, in healthy urine, is usually about one part in 1000, varies, in disease, from a scarcely perceptible trace to 5.5 in 1000 parts, and is occasionally even higher. When present in excess, they may generally be partially precipitated by warming the urine (49).

110. It sometimes happens, in certain forms of disease, that the earthy phosphates are secreted in much smaller

quantity than is found in healthy urine, and in some rare cases they appear to be altogether absent. Whether this is the case in any specimen of the secretion, may be ascertained by adding to it a slight excess of ammonia, when, if present only in very small proportion, or not at all, no precipitation will take place: or the ash of the urine may be digested in dilute hydrochloric or nitric acid, and the clear acid solution supersaturated with ammonia, when, if no precipitate is produced, it may be concluded that no perceptible trace of earthy phosphates is present.

II. *Urine containing one or more abnormal ingredients.*

111. The abnormal matters usually found in morbid urine are, 1, sugar; 2, albumen; 3, blood; 4, biliary matter; 5, pus; 6, fat and chylous matter; 7, semen; 8, oxalate of lime; 9, cystine; 10, iodine, and other foreign matters. Besides the substances just enumerated, various others may be occasionally detected in urine, such as arsenic, antimony, and many other saline and organic matters, which, having been taken into the system medicinally or otherwise, and being incapable of assimilation, have passed through either unchanged, or more or less modified in composition.

SECTION X.

Urine containing Sugar ($C_{12}H_{14}O_{14}$).

112. The variety of sugar always present in the urine of diabetic patients, and hence called diabetic sugar, has the same chemical composition as that contained in most kinds of fruit, commonly known as grape sugar or glucose. It appears to contain two equivalents of water of crystallization, which may be expelled at a temperature of 212°; so that its composition may be more correctly expressed by the formula ($C_{12}H_{12}O_{12}+2\,Aq$).

113. Diabetic sugar may be obtained by concentrating the urine containing it, by evaporation on a water bath, until it begins to deposit a crystalline sediment; the mass is then allowed to cool, on which the greater part of the sugar crystallizes out. It is then filtered; and when most of the liquid has passed through, the crystals are to be

pressed between folds of filtering paper, and washed with a small quantity of cold strong alcohol, which serves to remove the greater part of the impurities, without dissolving much of the sugar. The crystals are then dissolved in hot water, and purified by successive crystallizations, or, if necessary, by boiling with animal charcoal.

114. Diabetic sugar differs from cane sugar ($C_{12}H_{11}O_{11}$) in being considerably less sweet to the taste, harder, and less soluble in water; one part requiring about one and a half of cold water to dissolve it. In dilute alcohol, on the other hand, it is somewhat more soluble than the cane variety; but is insoluble in absolute alcohol and ether. It is usually in the form of granular crystals; but when crystallized out of a considerable mass of syrup, it is often obtained in needlelike tufts. When crystallized from its solution in dilute alcohol, it usually separates in the form of hard transparent cubes, and occasionally in square plates. An insipid modification of diabetic sugar has been met with in a few rare cases; it appears, in other respects, to possess the same properties as the common diabetic sugar.

115. Strong sulphuric acid dissolves grape sugar, forming a pale yellowish solution; cane sugar, on the contrary, is almost instantly charred and blackened by the strong acid.

116. Urine containing sugar is usually characterized by its high specific gravity, which is frequently from 1030 to 1045, and occasionally as high as 1050 and 1055. If, however, the sugar is present only in small quantity, the specific gravity may not be higher than usual; so that a moderately low specific gravity is of itself no proof of the absence of sugar.

117. Diabetic urine has usually, after standing a short time in a warm atmosphere, a white scum, somewhat resembling flour, on the surface, consisting of minute oval-shaped confervoid vesicles (132), which is highly characteristic of the presence of sugar, and occasionally leads to its detection before it has been secreted in sufficient abundance to raise the specific gravity of the urine to a suspicious extent.

118. This variety of urine is usually paler than the natural secretion, and frequently possesses a faint greenish tint. It is most commonly slightly turbid. When fresh, it has a faint and rather agreeable odour, somewhat resembling that of hay.

119. The proportion of urea in diabetic urine is usually

much smaller than that found in the healthy secretion; but whether the absolute amount secreted differs materially from the normal average, or whether the apparent deficiency is merely owing to the large quantity of water passed by diabetic patients, thus largely diluting the urea, has not yet been satisfactorily decided, owing to the difficulty of correctly estimating the quantity of urea when mixed with any considerable amount of sugar (334).

120. The proportion of sugar in diabetic urine varies from a mere trace, to from fifty to eighty parts in 1000; and has been known to amount to as much as 134 parts in 1000.

121. Several tests have been proposed for the detection of sugar in urine. Of these, the following only need here be noticed—viz., *Trommer's test*, *Moore's test*, the *fermentation test*, and the test afforded by the growth of a microscopic confervoid vegetation, called the *torula*.

122. *Trommer's test.* This excellent test is founded on the circumstance, that when a solution containing diabetic or grape sugar (112) is boiled with a mixture of potash (KO) and sulphate of copper (CuO,SO_3), the oxide of copper (CuO) contained in the latter becomes reduced to the state of suboxide (Cu_2O), which is precipitated in the form of a reddish brown or ochre-coloured granular powder.

123. A little of the urine suspected to contain sugar is placed in a tolerably large test tube, and mixed with a drop or two of a solution of sulphate of copper, which should be added only in sufficient quantity to give the mixture a very pale blue tint. This will probably cause a slight precipitation of pale blue phosphate of copper, owing to the presence of soluble phosphates in the urine (40); this, however, need not be regarded, as it will not afterwards interfere with the indications of the test. A solution of potash is now added in large excess,* or in quantity equal to about half the volume of urine employed; this will first throw down a pale blue precipitate of hydrated oxide of copper (CuO,HO), which, if sugar is present, will immediately redissolve, forming a purplish blue solution, something similar to that caused in a very dilute solution of copper by ammonia (797).

124. The mixture is now to be carefully heated over a lamp, and gently boiled for some minutes; when, if sugar is present, a reddish or yellowish brown precipitate of sub-

* Or the potash may be added, and the solution filtered from any deposit of earthy phosphates that may be thrown down, *before* the addition of the sulphate of copper.

oxide of copper (Cu_2O) will be deposited in the liquid. If no sugar is present, a black precipitate of the common oxide of copper (CuO) will be thrown down, totally distinct in appearance from the suboxide. It is important, in this experiment, not to add too much of the sulphate of copper, because, in that case, the suboxide might be mixed with some of the black oxide, (the sugar being capable of reducing only a certain definite quantity,) which would more or less mask the characteristic colour and appearance of the suboxide.

125. This test is extremely delicate, and is capable of detecting very small traces of sugar in the urine.

126. *Moore's test.* Mix a little of the suspected urine in a test tube, with about half its volume of liquor potassæ, and boil the mixture gently for about five minutes. If sugar is present, the liquid will assume a brownish or bistre tint; while little or no heightening of colour takes place when the urine is free from saccharine matter.

127. *Fermentation test.* This is perhaps the most valuable test for sugar which we possess, since it is not only capable of detecting it when present only in minute quantities, but also supplies a method of estimating the proportion contained in any specimen of urine. The mode of employing it in the quantitative determination of sugar will be described further on (333). When used merely as a qualitative test, to indicate whether sugar is or is not present, the following is the simplest way of applying it.

128. Fill a test tube with the suspected urine, having previously mixed with it a few drops of fresh yeast, or still better, a little of the dried German yeast; close the open end with a small saucer or evaporating dish, and while gently pressing the latter upon the tube, invert them, when they will be in the position shown in the figure (Fig. 14). A little more of the urine is then poured into the saucer, in order to prevent the escape of any of the liquid from the tube; and if any bubbles of air have accidentally been allowed to enter, the exact height of the upper surface of the liquid in the tube must be marked with ink, or with a strip of gummed paper. The tube, with its contents, is then set aside in a warm place, having a temperature of about 70° or 80°, for twenty-four hours. As bubbles of gas are sometimes given off by

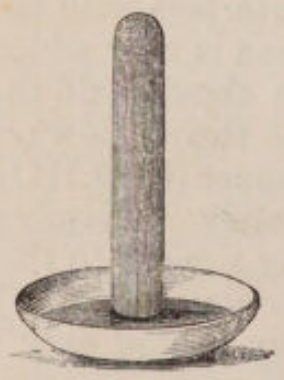

Fig. 14. Fermentation test.

the yeast itself, it is a good precaution to put the same quantity of yeast into a second tube of equal size, and fill it up with pure water. The amount of gas, if any, derived from the yeast, will thus be rendered apparent, and may afterwards be deducted from the volume of gas in the tube containing the urine.

129. If sugar is present it begins almost immediately to undergo the vinous fermentation, by which it becomes converted into alcohol (C_4H_5O,HO) and carbonic acid (CO_2), each equivalent of sugar giving rise to the formation of two equivalents of alcohol, four of carbonic acid, and two of water; thus:—

$$C_{12}H_{14}O_{14}=2(C_4H_5O,HO)+4CO_2+2HO.$$

The carbonic acid thus formed rises in minute bubbles, causing gradual and gentle effervescence, and collects in the upper part of the tube, at the same time displacing the liquid, which escapes through the open end of the tube into the saucer.

130. That the gas thus formed is really carbonic acid may be proved by decanting a little of it over water into a clean tube (Prac. Chem. 16), and testing it with lime-water, which will instantly become milky, owing to the formation of the insoluble carbonate of lime (CaO,CO_2). When the quantity of sugar present is at all considerable, the urine, after fermentation, will be found to possess a faint vinous smell, due to the alcohol formed during the process.

131. If, on the contrary, the urine is free from sugar, of course no fermentation will take place, and no gas will be formed in the tube.

132. *Test afforded by the growth of the torula.* During the process of the vinous fermentation of a liquid containing sugar, a delicate white scum gradually collects on the surface, which, when seen merely with the naked eye, is so highly characteristic an indication of the presence of sugar, as frequently to lead to its detection when present only in very small quantity. If a little of this scum be examined under the microscope, with a magnifying power of four or five hundred diameters, it will be found to consist of minute oval vesicles

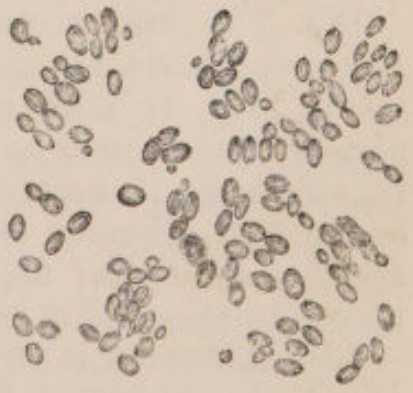

Fig. 15. Torula Vesicles, magnified 400 diameters.

(Fig. 15), which, in the course of a few hours, rapidly change their form, becoming longer and more tubular, and giving rise to new vesicles, which shoot out from the parent body, forming an irregularly jointed confervoid stem (Fig. 16). These again gradually break up into a great number of oval vesicles, which eventually separate, and fall to the bottom, where they may be detected by microscopic examination.

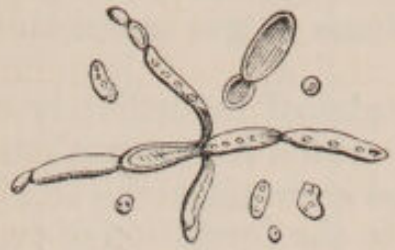

Fig. 16. Torula stem.

SECTION XI.

Urine containing Albumen.

133. This substance, which is contained, as is well known, in large quantity, in many of the tissues of the body, and especially in the serum of the blood (466), is not unfrequently present in morbid urine. Albuminous urine varies very considerably in appearance and general characters, being found alkaline, acid, and neutral; high coloured, and pale; of high specific gravity, and the contrary; so that no general rule can be laid down as to its usual physical peculiarities, likely to lead to its detection; though, when its presence is once suspected, its detection is easy and simple (139).

134. The quantity of albumen found in urine varies very much, a mere trace only being sometimes present, and at others as much as ten or twelve parts in 1000.

135. The most remarkable property of albumen is, that when a solution containing it, is heated to a temperature of about 170°, or higher, it coagulates, and separates completely from the liquid; and when this change has once taken place, it becomes quite insoluble in water. The coagulated albumen is readily soluble in potash and other alkaline solutions; and when an excess of alkali is present, no coagulation takes place on boiling.

136. Albumen is precipitated from its solution by nitric and hydrochloric acids, but not by phosphoric, acetic, or tartaric acids, which, indeed, appear to exercise a decided

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in alkaline solutions (135). On this account the urine should first be examined with turmeric or reddened litmus paper (277), and, if found to be alkaline, neutralized with nitric acid before boiling.

143. It should also be remembered, that when the albumen is present only in small quantity, the addition of a very slight excess of nitric acid may redissolve it, and thus lead to the supposition that the precipitate is phosphatic. A few drops more of the acid, however, will instantly cause it to reappear, if albuminous; while, if really phosphatic, no excess of the acid would cause it to do so.

144. The peculiar casts of urinary tubes, found in the urine of patients suffering from Bright's disease, consisting of fibrinous or albuminous matter, and entangling blood corpuscles, epithelium, and fatty globules, have usually the appearance shown in figure 17.

Fig. 17. Fibrinous Cast. (Dr. G. Johnson.)

SECTION XII.

Urine containing Blood.

145. Urine frequently contains, in addition to albumen, one or more of the other constituents of the blood (450), and is often more or less highly coloured red or brown, by the presence of the corpuscles and red colouring matter. When the fibrin, in its soluble form, is present, it usually coagulates spontaneously on cooling, and causes the urine to become more or less gelatinous soon after it is passed. This spontaneous coagulation on cooling, may be considered of itself sufficient proof of the presence of the fibrin of the blood.

146. The blood corpuscles may generally be detected both in the coagulum, and also in the superincumbent fluid, when examined under the microscope (451); occasionally, however, they are almost entirely disintegrated, so that little or no trace of their characteristic form remains. They are sometimes found adhering together, forming little thread-like aggregations; but more frequently floating detached

from each other, looking like little transparent rings (Fig. 18).

147. In urine containing blood, the albumen may in all cases be readily detected by the tests already mentioned (139)—viz., heat and nitric acid; but when any of the colouring matter of the blood is also present, it will coagulate with the albumen, giving the coagulum a more or less decided red or brown colour.

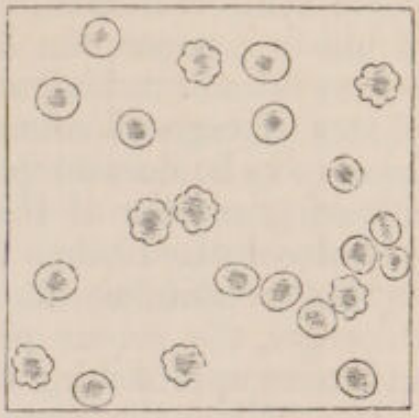

Fig. 18. Blood in urine.

SECTION XIII.

Urine containing Biliary matter.

148. When biliary matter is present in urine, it generally gives a more or less decided yellowish brown colour, both to the liquid, and also to any sediment that may be deposited from it. The taste also of such urine is remarkably bitter; a peculiarity which furnishes a ready indication of its presence when other tests are not at hand; though it must not be implicitly relied on, since small traces may exist in the secretion, without communicating to it any very decided taste.

149. *Pettenkofer's test.* Perhaps the best test for the presence of bile is that known as Pettenkofer's. If the urine contains albumen, it should first be freed from that substance by coagulation and filtration (135, 151); because albumen, when present in considerable quantity, would give, with sulphuric acid and sugar, a colour resembling that caused by bile. A little of the suspected urine is mixed in a test tube with about two-thirds its bulk of strong sulphuric acid, which must be quite free from sulphurous acid (SO_2), since the latter would, if present, tend to destroy the colour, and thus prevent the proper action of the test. The sulphuric acid should be added cautiously, drop by drop, in order to prevent the evolution of too much heat, since at a temperature of about 140°, or a little higher, the characteristic colour is destroyed. A grain or two of sugar, or of syrup, are now added to the acid liquid; and

the mixture is shaken, and allowed to stand a few minutes. If bile is present, the liquid will gradually assume a more or less intense red colour, with a tinge of violet. The cause of this change of colour is not clearly understood, but it appears to be occasioned independently of the biliphæin or colouring matter of the bile, since it is produced equally with decolorized bile. It must be borne in mind, that in liquids containing a considerable quantity of soluble chlorides, the colour produced by this test is less bright, and more approaching to brown.

150. When the quantity of bile is small, it is advisable, before applying the test, to concentrate the urine by evaporation. For this purpose it is first boiled, in order to coagulate any albumen that may be present (151), and afterwards evaporated nearly to dryness on a water bath. The residue is then treated with a small quantity of boiling water or alcohol; and the solution thus formed, containing any biliary matter that may be present, is mixed, when quite cold, with about one-third its bulk of strong sulphuric acid, observing the precautions already mentioned (149), and afterwards with sugar; when the characteristic red colour will appear, provided any biliary matter is present.

151. The experiment known as *Heller's test* is made as follows. Mix with a little of the suspected urine a few drops of the serum of blood or white of egg, or of any liquid containing albumen in solution; and having shaken them well together, add a slight excess of nitric acid, which will cause the precipitation of the albumen (136). If bile is present, the coagulum thrown down by the acid will have a more or less distinct dull green or bluish colour, quite different from the white or pale fawn colour which it would otherwise be. When only a small quantity of biliary matter is present, the urine may be concentrated, as in Pettenkofer's test (150), the serum or white of egg being subsequently added to the concentrated aqueous solution of the evaporated residue.

152. The following test may also be employed in proving the presence of bile in the urine. Pour a few drops of the suspected urine upon a clean white plate or dish, so as to form a thin layer of the liquid, and then carefully add a drop or two of nitric acid. When bile is present in any considerable quantity, the liquid becomes successively pale green, violet, pink, and yellow, the colour rapidly changing

as the acid mixes with the urine. When the bile is present only in small quantity, these colours are not distinctly visible; but unless the proportion is very minute, a greenish tint is generally perceptible. On concentrating the urine by evaporation, the appearance may be seen to greater advantage, when only small traces of bile are present (150). The action of this test appears to depend on the presence of the peculiar brown colouring matter of bile, called biliphæin.

SECTION XIV.

Urine containing Pus.

153. Pus is a substance which in many respects closely resembles mucus, both in its behaviour with reagents, and still more in its appearance under the microscope; so that it is not always easy to distinguish between them; and when mixed together in the urine, it is frequently quite impossible to say with certainty whether or not both are present. Like mucus, it consists of minute round or oval granular corpuscles (Fig. 19), floating in the fluid, from which they separate on standing, and gradually sink to the bottom. These form, in urine containing pus, a pale greenish yellow or cream-coloured layer, at the bottom of the fluid; and if shaken, the sediment readily breaks up, and diffuses itself through the liquid, again gradually subsiding to the bottom when allowed to stand.

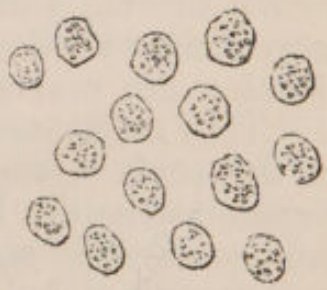

Fig 19. Pus in urine, magnified 400 diam.

154. Urine containing pus is met with sometimes neutral, acid, and alkaline. It always contains albumen in solution, which may be recognised in the filtered urine, by the usual tests, heat and nitric acid (139). This albumen is derived from the *liquor puris*, in which it is always present (254, 677). The absence of albumen, therefore, in the urine, may be considered as a strong indication of the absence of pus; though the presence of albumen is of itself no kind of proof of the existence of pus, since it may be derived from other independent sources. Traces of blood are by

no means unfrequent in purulent urine, giving the sediment a brown or reddish colour (145).

155. The chemical and microscopic characters of pus, and the modes of distinguishing it from mucus, will be more fully described further on (247 to 258, 674).

156. The peculiar granular corpuscles, which have been called *large organic globules*, and which are not unfrequently met with in certain conditions of the urine, especially in that of pregnant women, closely resemble the corpuscles of mucus and pus; being granular on the exterior, and on the addition of acetic acid, develop internal nuclei. They are, however, larger; and are unaccompanied by the albuminous and viscid fluids, which are characteristic respectively of pus and mucus (676, 661). Their general appearance is shown in figure 20.

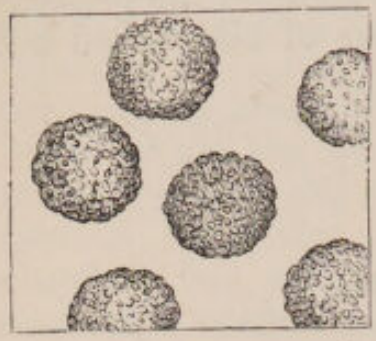

Fig. 20. Large organic globules, magnified 400 diameters.

157. The small circular bodies, which have been occasionally, though much more rarely, found in certain morbid conditions of the secretion, and called *small organic globules*, are represented in figure 21. They are spherical and smooth on the surface, no appearance of granular structure being apparent, and considerably smaller than the large organic globules (156). They are unaffected by acetic acid.

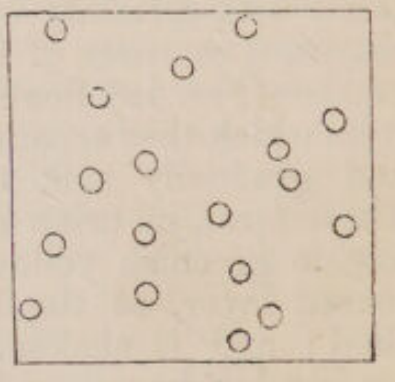

Fig. 21. Small organic globules.

SECTION XV.

Urine containing Fat and Chylous matter.

158. Urine containing fatty or chylous matter is usually more or less turbid, and frequently has an almost milky appearance. Little is known as to the precise nature of the fatty matter which is thus occasionally met with in urine, though it is probable that its composition varies with the circumstances under which it is formed. It sometimes

exists associated with albumen and chylous matter, sometimes alone. Numerous minute oily globules may in many cases be seen under the microscope (325), but it is often so intimately mixed with the albuminous matter also present, forming a kind of emulsion, that no trace of oily globules can be detected, even with a high magnifying power. In such cases, the urine may be agitated with a little ether, which will dissolve the fat; and the etherial solution thus formed will separate from the watery liquid, forming a distinct stratum floating on the surface. If the etherial solution be evaporated at a gentle heat, the fat will be left, and may be readily recognised by the physical peculiarities of fatty substances; such as immiscibility with water; breaking up into minute globules when agitated with hot water, &c.

Chylous urine frequently contains minute round corpuscles, resembling the white globules of the blood or lymph, which at first sight have a good deal the appearance of oil globules, for which they have probably been in some cases mistaken. Their insolubility in ether, however, shows that they are not always composed of fatty matter.

159. The peculiar form of mucilaginous or caseous matter, usually present in the urine of pregnancy, and which has received the name of Kiestein, gives the urine containing it a cloudy appearance; and after the lapse of a few days, gradually forms on the surface a more or less shining pellicle, which in three or four days, as the urine becomes ammoniacal, breaks up into minute particles, which subside to the bottom. When examined under the microscope, the pellicle is found to consist of minute granular particles, usually mixed with great numbers of prismatic crystals of triple phosphate (44), to which latter the peculiar shining appearance, somewhat resembling spermaceti, seems to be due. A few globules of oily matter, resembling butter, are also occasionally present.

SECTION XVI.

Urine containing Semen.

160. When semen is present in urine, it may easily be detected under the microscope, by the appearance of minute

animalcules, always found in the spermatic fluid, and hence called *spermatozoa*. They are more or less oval in form, and are furnished with long and delicate tails, as shown in Fig. 22. These spermatozoa, while in their native fluid, enjoy an active existence, and move about at will. In urine, however, unless a considerable quantity of pus is also present, they are never found alive, the secretion proving apparently fatal to them.

Fig. 22. Spermatozoa, and spermatic granules, magnified 400 diameters.

161. In addition to the spermatozoa, there may generally be recognised in seminal urine a few minute granular corpuscles, of a round or oval form (*a*, Fig. 22), and rather larger than the bodies of the animalcules. Traces of albumen also may generally be detected in urine containing semen (264).

SECTION XVII.

Urine containing Oxalate of Lime ($CaO,C_2O_3+2\,Aq$).

162. Urine containing oxalate of lime is usually, though by no means always, of a dark amber, and often of a pale greenish, or citron colour. It is in most cases decidedly acid to test paper, and is frequently found to contain an unusually large quantity of epithelial debris. Its specific gravity is not often materially different from that of the healthy secretion—viz., about 1020.

163. Oxalate of lime appears to exist very frequently in urine, generally in the form of minute and well-defined octohedral crystals (Fig. 23); but unless carefully looked for, it may readily escape detection, owing to the crystals, which are very transparent, having almost exactly the same refractive power as the urine itself, so that it is not always easy to distinguish them as they float in the liquid. The crystals have also nearly the same specific gravity as urine, in con-

sequence of which they generally remain suspended in the fluid some considerable time, before they form a sedimentary deposit at the bottom of the containing vessel.

164. The best way of detecting them is to allow the urine suspected to contain them to stand a few hours, that the oxalate may, in some measure, subside; though frequently it remains several days without doing so completely, in which case the urine may be passed through a filter, when most of the crystals will be retained by the paper, and may be warmed with a little distilled water, in the manner described below (165). The greater part of the liquid is then carefully poured off, and the lower stratum is placed in a watch-glass or small porcelain dish, and gently heated over a lamp. In this way the liquid will become specifically lighter, and in consequence the crystals, if present, will gradually subside to the bottom, especially if a slight rotatory motion be given to the liquid. It is now allowed to stand a few minutes, and the clear liquid is carefully poured off, or removed by means of a pipette.

165. A little distilled water may now be added, when the sediment will become much more distinctly visible, owing to the refractive power of the water differing more decidedly from that of the crystals. The mixture is again heated, when any urate of ammonia, which is often also present, will be dissolved; and by pouring off the liquid, after standing a few minutes, the crystals will be left at the bottom, and may be removed for the purpose of microscopic examination, or for testing with reagents.

166. Oxalate of lime, as found in the urine, is usually in the form of beautifully defined octohedral crystals (Fig. 23), of sizes varying from $\frac{1}{750}$th to $\frac{1}{5600}$th of an inch in diameter. When examined with polarized light, these octohedra will be found to have little or no action upon it, and remain invisible, or nearly so, when the field is dark.

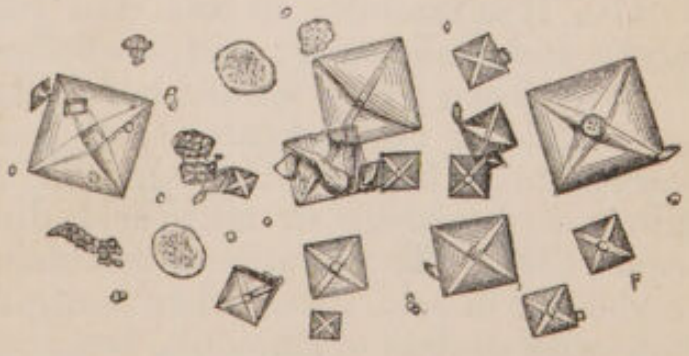

Fig. 23. Octohedral crystals of oxalate of lime.

167. When allowed to dry upon the glass, each crystal appears under the microscope, especially if the magnifying power is not very high, like a black cube, having in the centre a small white square opening, as shown in figure 24. This curious appearance is owing to the rays of light, from the greater part of the crystal being refracted beyond the field of vision. On again moistening them, the crystals reappear as before in their true octohedral form.

Fig. 24. Octohedra of oxalate of lime; seen when dry.

168. Oxalate of lime is not unfrequently met with in the urine, having the forms shown in figure 25 more or less resembling dumb-bells, with finely striated surfaces. This form of oxalate-of-lime sediment, unlike the octohedral variety (166), appears beautifully coloured and striated when examined with polarized light. If these "dumb-bells" be kept in any liquid medium for a length of time, they gradually pass into octohedra, which is their more natural form; so that when it is wished to preserve the dumb-bells, they should be put up in balsam, in which they will continue to retain their peculiar form.

Fig. 25. Dumb-bells of oxalate of lime.

169. Oxalate of lime is readily soluble, without effervescence, in dilute nitric and hydrochloric acids, from which it is again thrown down in the form of a white precipitate, when the acid solution is neutralized with ammonia or potash.

170. It is insoluble in both cold and hot water; also in acetic and oxalic acids; and in solution of potash.

171. When gently ignited before the blowpipe, it undergoes little or no blackening, and becomes converted into carbonate of lime (CaO,CO_2), which, when treated with dilute hydrochloric or nitric acid, dissolves with effervescence (399). The solution thus obtained by dissolving the carbonate in acid, gives, when neutralized, a white precipitate with oxalate of ammonia, but none with ammonia. If the oxalate be kept intensely heated for some little time before the blowpipe, the carbonate itself is decomposed, and caustic lime is formed (402).

SECTION XVIII.

Urine containing Cystine ($C_6NH_6O_4S_2$).

172. Cystine has occasionally, though but rarely, been found both as a crystalline deposit in urine, and also in the form of small calculi; in one of which latter, it was first discovered by Dr. Wollaston. A deposit of cystine, when examined under the microscope, usually appears as a mass of minute irregularly formed crystals, having the appearance shown in figure 26. To the naked eye, the deposit has a good deal the appearance of pale fawn coloured urate of ammonia (93), from which it may be readily distinguished by being insoluble, or nearly so, in warm water, and consequently not disappearing when the urine containing it is gently warmed (94).

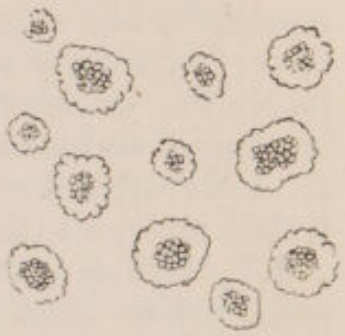

Fig. 26. Cystine.

173. One of the most characteristic properties of cystine is the readiness with which it dissolves in ammonia. If a little of the ammoniacal solution, thus formed, be allowed to evaporate spontaneously on a slip of glass, the cystine is deposited in minute hexagonal crystals, having the form and appearance shown in figure 27. It must be remembered that, occasionally, chloride of sodium crystallizes in octohedral masses (Fig. 28), which in some positions may have at first sight very much the appearance of cystine. The ready solubility of the chloride in water is, however,

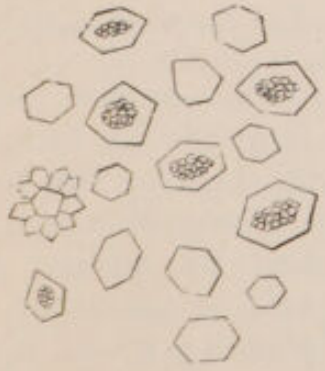

Fig. 27. Cystine crystallized from an ammoniacal solution.

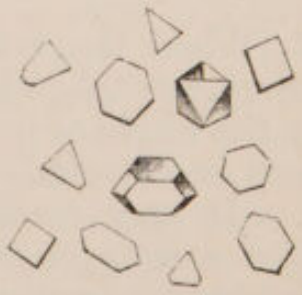

Fig. 28. Crystals of chloride of sodium, resembling cystine.

sufficient to prevent such a mistake. The crystals of cystine, too, when examined with polarized light, appear beautifully coloured, unless very thick, which is not the case with chloride of sodium. The triangular crystals of triple phosphate (44), which in some positions somewhat resemble cystine, may be at once distinguished by their ready solubility in dilute acids (49, 174).

174. Cystine is insoluble in a solution of carbonate of ammonia, but soluble in the fixed alkaline carbonates. It is very sparingly soluble in water, even when warmed, and insoluble, or nearly so, in alcohol. In acetic acid it is insoluble, and also in dilute nitric and hydrochloric acids. If, however, either of the two latter acids be in a concentrated state, a little of the cystine will be found to dissolve.

175. Urine containing cystine has usually a somewhat paler colour than the healthy secretion, with occasionally a greenish tint. Its specific gravity is most commonly rather low. It may generally be distinguished, when fresh, by a peculiar and slightly aromatic smell, a good deal resembling that of sweet brier: this gradually gives place to a fœtid, disagreeable odour, owing to the occurrence of putrefactive decomposition.

176. Cystic urine is, in most cases, slightly turbid when passed, and becomes considerably more so as it cools, the cystine being less soluble in the cold liquid. A small quantity of the cystine, however, is still held in solution, and may be precipitated by adding a little acetic acid to the filtered urine.

SECTION XIX.

Urine containing Iodine and other foreign matters.

177. When the compounds of iodine, as the iodide of potassium, are taken internally, it is generally found that nearly the whole of the iodine is carried off by the kidneys, and may be detected, in some form of combination, in the urine. It may readily be identified by adding to the secretion a drop or two of nitric acid or chlorine water, and then testing with a solution of starch; when, if iodine is present, the liquid will assume a more or less intense purple colour, owing to the formation of iodide of starch (807, 810).

178. Many other substances, taken into the system either

as food or medicinally, pass into the urine unchanged, and may frequently be distinguished by their peculiar properties. This is especially the case with many of the vegetable colouring matters, as those of indigo, madder, beetroot, gamboge, logwood, &c. Some of these may occasionally give rise to the suspicion of the presence of blood, but their real nature may generally be ascertained by examination under the microscope.

179. Besides these colouring matters, various other substances, both organic and inorganic, are occasionally found in urine. Thus, when any metallic preparation has been taken internally, traces of the metal, in some state of combination, may usually be found. The inorganic, and some of the organic acids also, are frequently to be detected; though, when neutral salts of the latter have been taken, carbonates of the bases are more usually found. In addition to these, the odorous principles of many vegetables appear to pass off unchanged in the urine, where they may often be recognised by their peculiar smell.

CHAPTER V.

QUALITATIVE EXAMINATION OF URINE SUSPECTED TO CONTAIN EITHER AN UNNATURAL PROPORTION OF SOME ONE OR MORE OF THE USUAL INGREDIENTS, OR ELSE SOME ABNORMAL MATTER.

180. It often happens that, owing to some peculiarity of colour and appearance, either of the liquid or sedimentary portion of morbid urine, or from some other circumstance, such as its high specific gravity, we are led to form some conjecture as to its real nature. When such is the case, one or two well-selected experiments, such as those about to be described, will generally be found sufficient to decide whether or not the suspected peculiarity really exists. When, however, the observer is unable to form a tolerably strong opinion as to the nature of the urine he is about to examine, he had better proceed to test it according to the directions given in Chapter VI.

SECTION I.

Examination of Urine suspected to contain Urea in abnormal quantity.

181. When the presence of an excess of urea is suspected, either on account of the high specific gravity of the urine (301), or from any other cause, a drop or two of the liquid should be placed on a slip of glass, and mixed with about an equal quantity of pure colourless nitric acid. If the urea is present in large excess, there will probably be a deposition of minute rhomboidal crystals of the nitrate in the course of a few minutes (Fig. 29), and if no trace of crystallization is visible to the naked eye, the mixture should be examined under the microscope. If no crystals appear in the course of half an hour or an hour, a few drops of the urine may be slightly concentrated by evaporation on a slip of glass, at a gentle heat; and when cool, mixed as before, with an equal quantity of nitric acid. Crystals of the nitrate will now separate, if any considerable quantity of urea is contained in the urine; and, from the rapidity with which the crystals form, together with their abundance, the student will be able, after a little practice, to form a tolerably accurate opinion as to the relative amount of urea present in the urine. If a microscope is not at hand, the experiment may be made, though less delicately, without it.

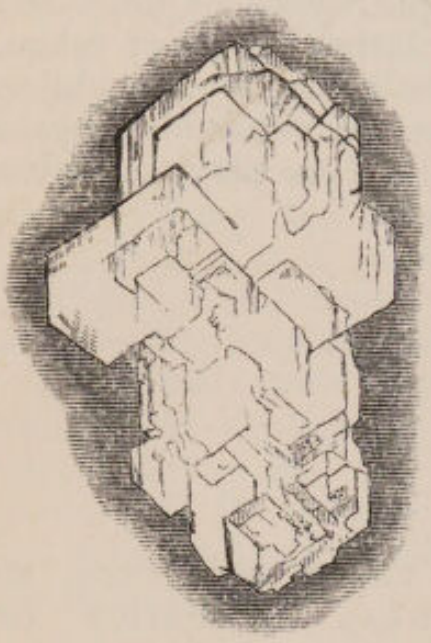

Fig. 29. Nitrate of urea.

182. It must be remembered that variations in the atmospheric temperature affect the crystallization of this salt very materially; in cold weather, a specimen of urine will consequently often be found to afford an abundant crop of crystals, which, in warm weather, would furnish

little or none. For this reason it is often advisable to cool the mixture artificially, by immersing the glass containing it either in cold water or a freezing mixture; which latter may be readily made by mixing a little pounded nitrate of ammonia with an equal weight of water.

183. If it is required to ascertain the absolute quantity of urea present, 1000 grains of the urine may be evaporated to dryness on a water bath, in a counterpoised porcelain dish, and the residue treated in the manner described in paragraphs 52 to 56.

184. When it is suspected that the urea is present in smaller quantity than in the healthy secretion, or is even altogether absent, 2000 grains of the urine are to be evaporated to dryness on a water bath, and the dry residue well stirred with successive small quantities of alcohol, which will dissolve any traces of urea that may be present. The alcoholic solution is then to be evaporated to dryness on a water bath, and the residue which it leaves is then treated in the manner described in paragraphs 341 and 342, in order to separate the whole of the urea, which may, if necessary, be weighed.

SECTION II.

Examination of Urine suspected to contain Uric (or Lithic) Acid in abnormal quantity.

185. When urine is suspected to contain an excess of uric acid, it may be examined in the following manner. Pour off the clear liquid from any solid deposit that may have subsided to the bottom, and retain both the solid and liquid portions for examination.

186. A little of the sediment is placed on a slip of glass, and examined under the microscope; when, if uric acid is present in it, either alone, or mixed with the amorphous or rounded particles of urate of ammonia (193), or other matters, it may be distinguished by its peculiar crystalline forms, most of the modifications of which are shown in the annexed figure (Fig. 30).

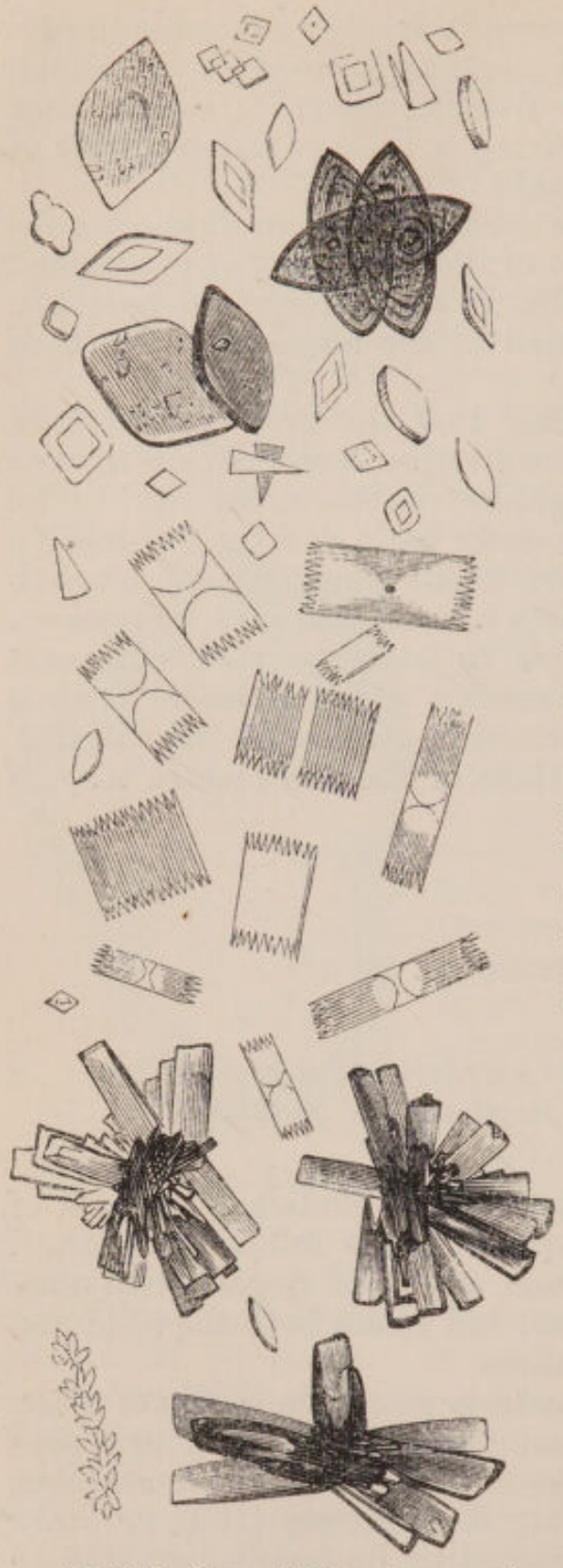

Fig. 30. Crystalline forms of uric acid.

187. If the sediment consists of uric acid, it will prove insoluble when the liquid is warmed. If urate of ammonia is also present, however, the latter will readily dissolve on the application of heat (192), leaving the crystalline uric acid unaffected.

188. Uric acid sediment is insoluble in dilute hydrochloric and acetic acids, but dissolves readily in a solution of potash, owing to the formation of the soluble urate of potash (22).

189. When uric acid is moistened with a little tolerably strong nitric acid, and the residue, after evaporation at a gentle heat, is treated, when cold, with a drop or two of ammonia, or exposed to ammoniacal fumes, a beautiful purple colour is developed, owing to the formation of murexide (23).

190. The clear urine, separated from the uric acid sediment (185), being still saturated with the acid, the latter may be gradually precipitated by adding a few drops of nitric or hydrochloric acid. The uric acid thus precipitated usually has the

crystalline forms shown in the upper and middle part of the figure.

191. When a deficiency of uric acid is suspected, the best way of ascertaining whether or not such is the case, is to filter one or two thousand grains of the urine, in order to separate the mucus and any other solid matter which it may contain, and which may be separately examined for uric acid under the microscope (186), or with nitric acid and ammonia (189). The filtered urine is then evaporated nearly to dryness, on a water bath, and the residue digested with dilute hydrochloric acid, containing one part of strong acid to eight or ten of water. Any uric acid that may be present will thus be left undissolved, and may be examined under the microscope, or otherwise; and, if necessary, weighed, after being first dried at a temperature of 212° on a water bath.

SECTION III.

Examination of Urine suspected to contain an excess of Urate (or Lithate) of Ammonia.

192. When a sediment is suspected to consist, either wholly or partially, of urate of ammonia, a little of the urine containing it is to be warmed over a spirit lamp. If it consists of urate of ammonia unmixed with other matters, it will readily dissolve as the liquid becomes warm, and, on cooling, will be again precipitated. When purpurine is present (104), the urate will probably not dissolve quite so readily on the application of heat as when it is unmixed with colouring matter.

193. Under the microscope, urate of ammonia appears as an amorphous powder, frequently interspersed with minute round particles larger than the rest, some of which are occasionally found adhering closely together. (See Fig. 11, paragraph 91.) More rarely, it is found in the form of large masses, containing spiculæ of superurate of ammonia (Fig. 12, paragraph 92).

194. It must be remembered that phosphate-of-lime sediment usually has a very similar appearance under the microscope (108), and may consequently be mistaken for

urate of ammonia, if the microscopic appearance alone be relied upon. All that is necessary, in order to distinguish between them, is to add a drop of dilute hydrochloric acid to a little of the deposit on a slip of glass. If it consists of phosphate of lime, it will instantly dissolve on the addition of the acid (49, 322); while, if urate of ammonia, it will be acted on much more slowly, and in a short time, minute crystals of uric acid (Fig. 31) will gradually appear, having been displaced from the urate by the action of the hydrochloric acid (196).

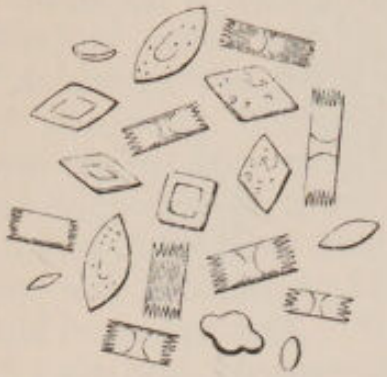

Fig. 31. Uric acid.

$$NH_4O,C_{10}N_4H_4O_6+HCl=NH_4Cl+HO+C_{10}N_4H_4O_6.$$

195. When uric acid coexists in a sediment with urate of ammonia, which is of very common occurrence, it may be distinguished under the microscope, by its crystalline forms (186), totally different from the amorphous or rounded particles of urate of ammonia. The uric acid would also be left undissolved when the liquid is warmed, and may then, if necessary, be separated by filtration, and further examined.

196. Urate-of-ammonia deposits are not unfrequently found mixed with the earthy phosphates, especially when the urine has at all an alkaline reaction. These will be left undissolved when the liquid is warmed, and may be examined under the microscope, and tested with dilute hydrochloric acid (317, 322).

197. When albumen is present in urine containing a sediment which is supposed to consist of urate of ammonia, it may, by coagulating when heated, disguise the solubility of the urate, and thus lead to an erroneous opinion as to the nature of the deposit. If, however, the heat be applied very gradually, the urate of ammonia will be found to dissolve some time before any of the albumen coagulates; so that, with care, this source of error may be avoided. Or if the urine has been inadvertently allowed to boil, and a precipitation of albumen has taken place, the liquid may be filtered *while hot*, and the clear filtered solution will, on cooling, again deposit the urate of ammonia; which may then, if necessary, be further examined (94, 192).

198. If pus or mucus be contained in the sediment,

together with urate of ammonia, the urine will not become perfectly clear on the application of heat; nor will those substances dissolve on the addition of dilute hydrochloric acid. They may, however, be distinguished with the aid of the microscope (328, 329).

199. When it is required to estimate the quantity of urate of ammonia in a urinary sediment, a portion of the latter, derived from a known quantity of the secretion, is to be boiled with water, and filtered while hot; when the soluble urate will be separated from any uric acid, earthy phosphates, &c., that may be also present with it. The solution is then concentrated by evaporation at a gentle heat, and allowed to cool; when the urate of ammonia will again separate in the solid form, and after drying on a water bath, may be weighed.

SECTION IV.

Examination of Urine suspected to contain Urate (or Lithate) of Soda.

200. When gently warmed, the deposit dissolves, similar to urate of ammonia, and reprecipitates on cooling.

201. Under the microscope, it usually appears in the form of small circular, and sometimes semi-crystalline grains, covered occasionally with irregularly formed spiculæ, or granular protuberances, as shown in figure 13, paragraph 96.

202. When ignited before the blowpipe on platinum foil, it leaves an abundant white fusible residue of carbonate of soda, which is readily soluble in water, forming a solution which is strongly alkaline to test paper.

203. If the ignited residue be treated, on a slip of glass, with a drop of dilute hydrochloric acid, it dissolves with effervescence, forming chloride of sodium; which, if the liquid be expelled by gentle evaporation, is gradually deposited in minute cubical crystals, on the glass, and may be easily recognised with a lens or microscope (Fig. 32).

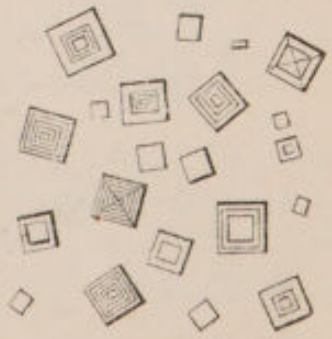

Fig. 32. Chloride of sodium.

204. When a little of the deposit, previous to ignition, is placed in a drop of nitric acid on a slip of glass, and the residue, after evaporation, treated with a little ammonia, in the manner described in paragraph 23, a purple colour is developed, similar to that caused under the same circumstances, with uric acid and urate of ammonia.

205. Urate of soda may be distinguished from urate of ammonia, which in chemical properties it much resembles, by its microscopic appearance (91, 96); by not being entirely dissipated by ignition (202, 375); by giving no ammoniacal fumes when warmed with a solution of potash (377); and by the ignited residue yielding with hydrochloric acid, cubical crystals of chloride of sodium (203).

SECTION V.

Examination of Urine suspected to contain an excess of Hippuric Acid.

206. When urine is suspected to contain an excess of hippuric acid, an ounce or so of the liquid is evaporated on a water bath to the consistence of a syrup; which is then mixed with about half its bulk of strong hydrochloric acid.

The mixture is set aside, and examined after the lapse of a few hours. If any considerable excess of hippuric acid is present, it will gradually crystallize at the bottom of the dish, in fine tufts of needlelike crystals, often coloured pink by the admixture of purpurine, and having the form shown at *a*, figure 33.

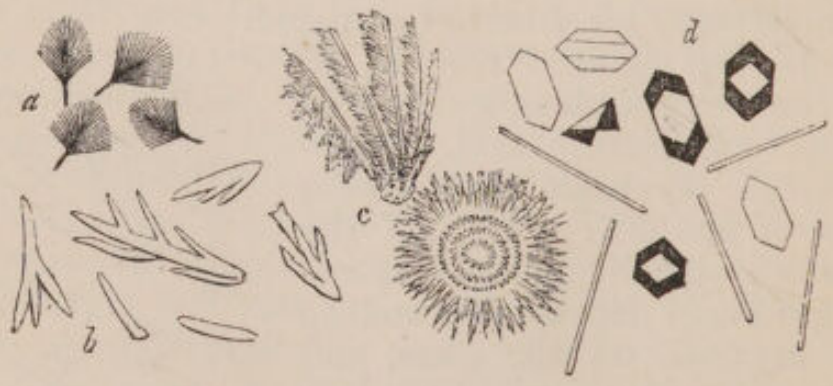

Fig. 33. Hippuric Acid.

207. If the acid is present in smaller quantity, there may be merely a few detached microscopic needlelike or branched crystals, deposited here and there upon the glass, as shown at *b* in the figure.

208. Hippuric acid is readily soluble in alcohol; the alcoholic solution leaving, after evaporation, a crystalline residue, which has usually the appearance shown at *c*, figure 33.

209. It is nearly insoluble in cold water, but readily soluble in hot. On cooling, the aqueous solution deposits the acid in well-defined prismatic crystals, which are either detached, as in *d* (Fig. 33), or in tufts, as shown at *a*. These crystals usually form very beautiful objects under the microscope; and when examined with polarized light, develop colours of great variety and brilliancy.

SECTION VI.

Examination of Urine suspected to contain an excess of Mucus.

210. Mucous urine always deposits a viscid, tenacious mass, having an alkaline reaction (100), and consisting chiefly of mucus, often mixed with the earthy phosphates, oxalate of lime, and other matters. If the urine be shaken, the deposit does not again mix uniformly with the liquid, but remains cohering in ropy masses, which are very characteristic.

211. When, owing to the admixture of a large quantity of earthy phosphates, the deposit has no longer the property of cohering together, the microscope must be resorted to, in order to determine whether or not much mucus is present; the appearance and abundance of the peculiar granular corpuscles (315, 328) furnishing a rough index of the quantity present.

212. It is possible that pus may also be present, in which case, unless in very small quantity, it may generally be detected in the manner described further on (247—258, 156), where will be found the means of distinguishing between pus and mucus.

213. If it is wished to determine the amount of muc

contained in a deposit, in which it is mixed with earthy phosphates, urates, &c., the sediment must be filtered, and boiled with a little water, in order to dissolve out the urates; it may then be treated with a little very dilute hydrochloric acid, which will dissolve out the earthy phosphates, when the residue of mucus may, after careful drying on a water bath or in a hot water oven (Prac. Chem. 630), be weighed.

SECTION VII.

Examination of Urine suspected to contain an abnormal proportion of Extractive Matter.

214. It is often of some importance to be able to identify the presence of an excess of the peculiar yellow colouring matter, of which the bulk of the extractive matter of urine appears to consist; and also that of purpurine, which is probably a morbid modification of the yellow substance.

Yellow colouring matter.

215. An excess of the yellow colouring matter may be recognised by boiling a little of the suspected urine, and then adding to it a few drops of hydrochloric acid. A more or less intense red colour is in this way produced; the intensity of the colour indicating the comparative amount of the yellow colouring matter present. In healthy urine, a faint lilac or pinkish tint only is caused by the hydrochloric acid; while if the colouring matter is in large excess, an exceedingly intense crimson is produced.

Purpurine.

216. The presence of purpurine, or the red colouring matter so often met with in cases even of very slight derangement of the system, is easily ascertained. Owing to its solubility in water or urine, it is never met with as a deposit *per se*.

217. Purpurine, however, has a remarkable tendency to

unite with urate of ammonia (104), and whenever a deposit of that substance is formed in urine containing purpurine, the latter is invariably precipitated with it, giving the sediment, which would otherwise be colourless, or nearly so, a more or less decided pink or red colour. When purpurine is present in a deposit of urate of ammonia, the latter is not so easily soluble in hot water, so that the red deposit does not disappear so readily on the application of heat, as when no purpurine is present (94).

218. If a deposit of urates, coloured with purpurine, be digested in warm dilute alcohol, the purpurine will dissolve, leaving the deposit nearly colourless, and forming a solution of a yellowish pink colour.

219. Urine containing purpurine, when no excess of urates is present, has a more or less decided pink or red colour, which may appear at first sight very similar to blood.

220. Purpurine may be distinguished from blood, when present in a sediment, by microscopic examination, when the true nature of the uric deposit will be at once apparent (318, 323), together with the absence of blood discs (330). When treated with warm alcohol also, the colouring matter will be dissolved out (218).

221. Purpurine, when contained in solution in urine, may be precipitated by adding a little warm aqueous solution of urate of ammonia, which will, on cooling, separate from the liquid, carrying with it nearly the whole of the colouring matter, forming a pink deposit, and leaving the urine nearly colourless.

SECTION VIII.

Examination of Urine suspected to contain an abnormal proportion of fixed Alkaline Salts.

222. When an excess or deficiency of any of the fixed alkaline salts is suspected to be present, a known weight of the urine may be taken, from which the proportion of the substance in question is estimated in the manner described in Chapter II., paragraphs 66 to 84.

SECTION IX.

Examination of Urine suspected to contain an abnormal proportion of Earthy Phosphates.

223. If the suspected urine is neutral or alkaline to test paper, a sediment of earthy phosphates may be precipitated, even in cases where they do not exist in larger proportion than in the healthy secretion; so that the mere occurrence of a small phosphatic deposit is not *necessarily* a proof of their excess (107).

224. On warming the urine, the sediment, if phosphatic, remains undissolved (94, 229).

225. The earthy phosphates are readily soluble in most of the dilute acids, especially hydrochloric, nitric, and acetic.

226. If the acid solution thus formed be neutralized or supersaturated with ammonia, the earthy phosphates are immediately reprecipitated (49 *b*).

227. They are quite insoluble in potash, ammonia, and the alkaline carbonates (49 *c*).

228. A deposit of earthy phosphates may generally be immediately recognised under the microscope. The crystalline forms of the triple magnesian phosphate have been already noticed (44), and these are often mixed with the amorphous phosphate of lime (Fig. 34). If a drop of dilute hydrochloric or acetic acid be added, while the sediment is in the field of the microscope, the crystals will be seen rapidly to dissolve, leaving the liquid clear, unless uric acid, or some other matter insoluble in the acid, be also present in the deposit.

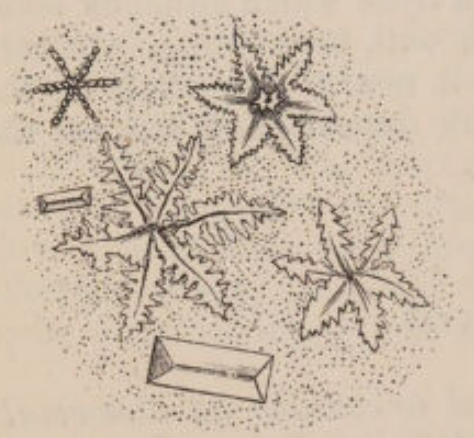

Fig. 34. Mixed Phosphates.

229. When urine, containing in solution an excess of earthy phosphates, is boiled, a portion of them is usually precipitated, giving the liquid a turbid appearance, resembling the coagulation of a small trace of albumen under similar circumstances (49,139). It may readily be distinguished from albumen, by adding a drop or two of dilute

nitric or hydrochloric acid, which will immediately redissolve the precipitate if it consists of phosphates; but if albuminous, will not affect it. When the precipitate is found to dissolve on the addition of the first drops of acid, it is advisable, before concluding that albumen is not present, to acidify the mixture more strongly, since the coagulum of albumen, when very small in quantity, occasionally dissolves on the first application of acid, but is wholly reprecipitated on the addition of a few drops more of the acid (140—143).

230. If the absence or a deficiency of the earthy phosphates is suspected, the urine may be treated with a slight excess of ammonia; when, if no precipitate occurs, it may be inferred that they are either altogether absent, or else present in very small quantity.

231. In order to ascertain, in such a case, whether or not any traces of them are present, a pint or two of the urine may be evaporated to dryness, and the residue, after incineration, digested with dilute hydrochloric acid, which will dissolve out the earthy salts if any are present. The acid solution thus obtained is then filtered, and supersaturated with ammonia, when, if any earthy phosphates are present, they will be thrown down in the form of a white precipitate (49 *b*).

Quantitative determination of the Earthy Phosphates.

232. When it is required to estimate the proportion of earthy phosphates in a deposit containing uric acid and other matters, a portion of the sediment, derived from a known quantity of urine, is first washed with a dilute solution of ammonia, and then digested with dilute hydrochloric acid, until the latter ceases to dissolve anything further. The acid solution of the earthy salts, thus obtained, is separated from the insoluble matter by filtration, and then supersaturated with ammonia, which will throw down the whole of the earthy phosphates (70). The mixture, after standing a short time, to allow the magnesian phosphate (73) wholly to separate, is to be filtered; and the precipitate, after drying at a gentle heat, is to be weighed, when its weight will represent the amount of earthy phosphates in the quantity of urine from which it was derived.

SECTION X.

Examination of Urine suspected to contain Sugar.

233. When urine is suspected to contain sugar, it may be examined by means of Trommer's test (122), and the fermentation test (127).* If any white scum or sediment is present, it should also be examined for the torula vesicles, under the microscope (132).

234. The method of estimating the quantity of sugar contained in diabetic urine will be fully described in Chapter VII.

SECTION XI.

Examination of Urine suspected to contain Albumen.

235. A little of the suspected urine is to be gently boiled in a test tube. If any albumen is present, it will be coagulated, forming a more or less copious white deposit in the liquid. The precautions necessary for the success of this experiment have been already noticed in paragraphs 139 to 143.

236. To another portion of the urine add a few drops of nitric acid, observing the precautions mentioned in paragraph 143. If a precipitate or milkiness be produced by the acid, and also by boiling (235), the presence of albumen in the urine may be considered certain (141).

237. The proportion of albumen in urine may be estimated with tolerable accuracy, by boiling a known quantity of the secretion, and separating the coagulum by filtration; the insoluble matter is then washed with a little dilute nitric or hydrochloric acid, in order to dissolve out any earthy phosphates that may have been precipitated (140), dried on a chloride of calcium bath at a temperature of about 240° or 250°, and weighed.

* Even when Trommer's test affords tolerably decided indications of sugar, it is always more satisfactory, when practicable, to confirm the result by the fermentation test; since certain other organic matters besides sugar, might, if present, cause the formation of the suboxide of copper.

238. If the quantity of albumen is so small as not to form a tolerably decided coagulum when boiled, but only to render the liquid opalescent, it will be hardly necessary to proceed with the quantitative determination; and it may be set down as a mere trace.

239. The method of making a complete quantitative analysis of albuminous urine will be fully described in Chapter VIII.

SECTION XII.

Examination of Urine suspected to contain Blood.

240. When, from its peculiar red or brown colour, or from other circumstances, the presence of blood is suspected in urine, it may first be examined under the microscope, for any blood-corpuscles that may be contained in it (146). If no coagula have separated (145), the liquid should be allowed to repose for a short time, in order to let the corpuscles subside to the bottom; and a drop then taken from the bottom of the vessel will generally be found to contain an abundance of the corpuscles, more or less modified in form and appearance (456).

241. When so much blood is present as to give the urine a decidedly red colour, it will probably be unnecessary to wait for the subsidence of the corpuscles; and a drop of the liquid taken indiscriminately will usually be found to contain sufficient for microscopic examination.

242. If the blood has coagulated, either in the bladder, or subsequent to emission, it is most probable that the greater portion of the blood-corpuscles will have been entangled in the coagula, and may be forced out by gentle pressure under a strip of thin glass, so as to be made visible with the help of the microscope.

243. The urine should also be tested for albumen by heat and nitric acid, in the manner already described (139—143). The coagulated albumen will probably, in this case, be more or less highly coloured, owing to the presence of the colouring matter of the blood (147, 455). If the urine already contains coagula, or other solid matter, it should be separated from them by filtration, before being tested for albumen; as their presence would tend to mask the appearance of coagulation.

244. If the urine contains much blood, it may probably become spontaneously gelatinous, owing to the coagulation of the dissolved fibrine (145, 448). This coagulum should be examined under the microscope, since a somewhat similar gelatinous character might be occasioned by the presence of a considerable quantity of mucus (101); or, if the urine be alkaline, of pus (251, 680). The coagulum of fibrine, when pressed between glasses, is usually found to be composed of minute amorphous particles, with a few red blood-corpuscles; quite different in character from the granular mucus corpuscles (146, 328).

245. Urine containing bile or purpurine (148, 104), has sometimes nearly the same colour and appearance as when blood is present, and may, without care, be inadvertently mistaken for it. If no trace of blood-corpuscles can be detected under the microscope, we should, before deciding that blood is present, prove that the colour of the secretion is not due to purpurine or biliary matter, by applying the tests described for the detection of those substances, in paragraphs 219—221, 246, &c.

SECTION XIII.

Examination of Urine suspected to contain Biliary matter.

246. When urine is suspected to contain biliary matter, it may be examined by Pettenkofer's and Heller's tests, described in paragraphs 149 and 151. If these fail to afford indications of it in the urine, the latter should be concentrated by evaporation on a water bath, and the strong aqueous or alcoholic solution of the evaporated residue again tested (150).

SECTION XIV.

Examination of Urine suspected to contain Pus.

247. When pus is contained in urine, unmixed with any considerable quantity of mucus, it may readily be distinguished under the microscope by its containing the peculiar nucleated pus granules (153, 678). These particles, when

the urine is allowed to stand a short time, gradually subside to the bottom of the liquid; and when shaken, again mix readily with the urine, in which respect a deposit of pus differs essentially from one of mucus; the latter forming, on agitation, tenacious ropy masses, which do not again mix uniformly with the liquid (99).

248. As purulent deposits frequently appear to the naked eye very similar to those of the earthy phosphates (106), and as it is often difficult to distinguish between pus and mucus when they coexist in a specimen of urine, I will mention the more characteristic tests by which purulent deposits may be most readily identified.

249. It must be remembered that the form and general appearance of the pus and mucus corpuscles vary considerably under different pathological conditions of the patient; so that it is not unfrequently impossible to distinguish between them. The granules of pus appear indeed to be identical with those of mucus; the difference between the two substances being in the composition of the fluid in which the particles float (661, 676).

250. Under the microscope, with a power of about 400 diameters, the pus granules have the appearance represented at *a*, figure 35; and on the addition of a little dilute acetic acid, they become much more transparent, and in each corpuscle one or more internal nuclei are rendered visible, having the appearance shown at *b* in the figure. The granules of pus will be found to float about freely in the liquid (678, 156).

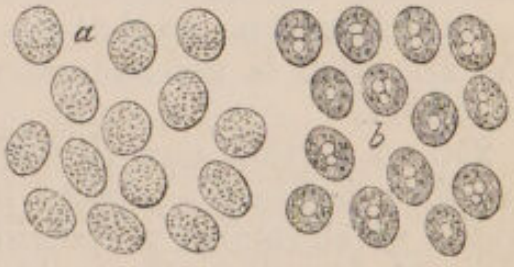

Fig. 35. Pus Granules.

251. When the urine is alkaline, the character of the pus contained in it is different; being then thick and gelatinous, closely resembling mucus (680).

252. The granules of mucus present almost precisely the same appearance under the microscope as those of pus, but are usually, perhaps, rather smaller, and less distinctly granular on the surface. The addition of dilute acetic acid renders visible the interior nuclei, as in the case of pus (250). The acid, however, coagulates the fluid portion of the mucus, owing, probably, to the precipitation of the mucin, before held in solution by a small quantity of

alkali (663). In the case of urine containing only a small quantity of mucus, it is uncertain whether this phenomenon of coagulation will be seen, on account of the dilution of the mucous fluid, and also because the coagulation may have been already occasioned by the presence of the large quantity of water (663). When, however, the quantity of mucus is tolerably abundant, the coagulation by acetic acid furnishes a very characteristic reaction.

253. The earthy phosphates, which to the naked eye, sometimes closely resemble pus, may be at once distinguished under the microscope by their crystalline form (43), and also by being readily soluble on the addition of dilute acetic acid (228).

254. The *liquor puris*, in which the pus granules float, always contains albumen in solution (676). This may be readily detected by the tests of heat and nitric acid, already described (139); unless, indeed, the quantity of urine is so large, compared with that of the pus contained in it, as to have rendered it too dilute.

255. The fluid portion of mucus, on the contrary, contains no albumen, or merely a minute trace (663), and consequently undergoes no coagulation when heated, or tested with nitric acid. It is, however, very possible that urine containing an excess of mucus, and no pus, may also contain albumen; so that the mere presence of albumen in the secretion is not necessarily a proof of the presence of pus (101).

256. A certain quantity of fatty matter, readily soluble in ether, is always present in pus (676, 678), but seldom, and in much smaller proportion, in mucus (663). If, therefore, the deposit, or the residue after evaporation, be boiled with a little ether, and the etherial solution thus obtained is found to yield, on evaporation, small globules of yellowish fat, it is probable that pus is present.

257. A deposit of pus, when treated with a solution of ammonia or potash, becomes converted into a thick gelatinous mass, often sufficiently tenacious to allow of the tube containing it to be inverted without any of the mixture flowing out. This reaction is very characteristic.

258. Urine containing pus is most commonly either neutral or slightly acid, and becomes alkaline very slowly. Mucous urine, on the contrary, even if acid when it is passed, quickly becomes ammoniacal, and alkaline to test paper (100).

SECTION XV.

Examination of Urine suspected to contain Fat or Chylous matter.

259. Urine suspected to contain fat, may be examined with a tolerably high power under the microscope, when it is occasionally found to contain minute oil globules (158, 325). This, however, is not always the case; so that the best way of proving the presence of fatty matter, is to agitate a little of the suspected urine with about half its bulk of ether, which will separate the fat from the watery fluid, forming, usually, a yellowish solution, which gradually rises to the surface. The etherial solution thus obtained, may then be cautiously evaporated on a water bath, when the fat or oily matter will, if present, be left behind; and may, if necessary, be tested as to its oily nature, by shaking up with hot water, when, if oil or fat, it will break up into minute globules, immiscible with the water (158).

260. Chylous urine is usually so peculiar in appearance, that it can hardly be mistaken for any other morbid condition of the secretion. Under the microscope, it appears to be chiefly composed of amorphous albuminous matter in a minute state of division, mixed occasionally with globules resembling those found in the lymph and chyle. On agitation with ether, it will yield abundant traces of fatty matter, and distinct oily globules may occasionally be distinguished.

261. This form of urine always contains albumen in solution. A portion of this, or more probably a little soluble fibrin (145), not unfrequently coagulates spontaneously after emission, giving the urine a gelatinous or semi-solid consistence. The presence of albumen may be shown by applying to the urine, rendered clear by filtration, the tests of heat and nitric acid (235).

262. If it is required to ascertain the quantity of fatty matter in any specimen of urine, a known weight of the secretion may be agitated with successive small quantities of ether; and the etherial solution thus obtained will leave, after evaporation, the fatty matter which it had dissolved. This is to be dried on a water bath until it ceases to lose any further weight.

SECTION XVI.

Examination of Urine suspected to contain Semen.

263. Microscopic examination is the only trustworthy means of determining whether or not any traces of semen are contained in urine. The urine should be well shaken, and then left to stand a short time, in order to allow the flocculi of mucus and spermatozoa to subside. The greater part of the fluid is then poured off, and a drop, containing the sediment, taken from the bottom, and examined under the microscope, with a magnifying power of at least four or five hundred diameters. If semen is present, the spermatozoa always contained in that secretion will then be visible (160), together, probably, with the peculiar seminal granules also found in the spermatic fluid (161).

264. Traces of albumen, also, may generally be detected in seminal urine, by the application of heat and nitric acid (235).

SECTION XVII.

Examination of Urine suspected to contain Oxalate of Lime.

265. When the presence of oxalate of lime is suspected, the urine should be allowed to stand some little time, in order that the sediment may partially subside. A little of the liquid taken from the bottom of the vessel is then treated in the manner described in paragraph 164, and examined under the microscope; when, if present, the oxalate will be seen either in the form of octohedral crystals (166), or of one or more of the modifications of the dumb bell (168).

266. Oxalate of lime dissolves without effervescence in dilute hydrochloric acid, and is again precipitated unchanged, when the acid solution is neutralized or supersaturated with ammonia or potash.

267. If the oxalate-of-lime deposit be gently ignited, and the residue after ignition treated with dilute hydrochloric acid, it will be found to dissolve with effervescence, having been converted, during ignition, into the carbonate of lime (399).

268. When it is required to estimate the amount of oxalate-of-lime sediment, it may, if unmixed with other deposits, be separated by filtration from a known quantity of urine, and weighed. When mixed with earthy phosphates or urates, the deposit, after filtration, may be washed with a little dilute acetic acid to dissolve out the phosphates (49 *b*); the mixture is then filtered, and the insoluble portion digested in dilute hydrochloric acid, which will dissolve the oxalate of lime, leaving undissolved any uric acid that may be present. The acid solution is then filtered, if necessary, and supersaturated with ammonia; by which the oxalate will be again precipitated. It may then be dried on a water bath, and weighed.

SECTION XVIII.

Examination of Urine suspected to contain Cystine.

269. The presence of cystine may generally be identified by means of the microscope (172), especially after the deposit has been dissolved in ammonia, and allowed to crystallize, either spontaneously or with the aid of a very gentle heat, from the ammoniacal solution (270).

270. Treat a portion of the suspected deposit with a little solution of ammonia; if it is cystine, it will be found readily to dissolve. Place a drop of the ammoniacal liquid on a strip of glass, and allow it to evaporate spontaneously. The peculiar hexagonal tabular crystals of cystine thus obtained are very characteristic (173).

271. Neutralize the rest of the ammoniacal solution formed in 270, with acetic acid; the cystine, if present, will be precipitated (174).

272. Cystine may be distinguished from urate of ammonia, which it often closely resembles in external appearance, by being insoluble, or nearly so, when the urine containing it is warmed; while urate of ammonia readily dissolves (172, 94).

273. It may be distinguished from the earthy phosphates by its insolubility in acetic acid (174); by its appearance under the microscope (317, 320); and also by its ready solubility in ammonia (173). From chloride of sodium, cystine may be distinguished by its sparing solubility in water (173).

274. If cystine be boiled with a little caustic potash, and the solution tested with acetate of lead, a black precipitate of sulphide of lead will be produced; in consequence of the large amount of sulphur contained in the cystine ($C_6NH_6O_4S_2$).

SECTION XIX.

Examination of Urine suspected to contain Iodine, or other foreign matters not included in the foregoing sections.

275. When the presence of any other kind of foreign matter is suspected in the urine (180), such as metallic salts, iodine, inorganic or organic acids, &c., a few tests, such as hydrosulphuric acid, hydrosulphate of ammonia, &c., will generally lead to their detection without much difficulty. (See Parts IV. & V.; also Prac. Chem., Parts II. & III.) If the suspected substance is organic, either the urine itself or the evaporated residue may be tested; but when an inorganic substance is to be looked for, it is generally advisable to incinerate the evaporated residue, and test the ash for the substance in question.

CHAPTER VI.

EXAMINATION OF MORBID URINE, THE NATURE OF WHICH IS ALTOGETHER UNKNOWN.

276. When a specimen of urine is suspected to differ in some respect from the healthy secretion, it will generally be found easy, by means of a very few simple experiments, such as those which I am about to describe, not only to ascertain whether or not such is the case, but also to discover the nature of the particular morbid condition in question; whether it be that one or more of the normal constituents of healthy urine is present in an abnormal proportion, or whether it be due to the presence of some substance which is never found in the healthy secretion. In such an examination, the microscope will be found to

afford most valuable and ready assistance, the simple microscopic inspection of a deposit often rendering its true nature at once apparent. Whenever, therefore, the student has access to one, he will do well to avail himself of it as much as possible; and he will soon find that, with a little experience, he will be able readily to discriminate between the more common forms of urinary deposits.

For the method of distinguishing the several forms of deposit under the microscope, see paragraphs 315 to 332.

SECTION I.

Examination of Urine containing some Solid Deposit.

277. The urine may be first tested with blue litmus paper; if acid, the colour will change to red, or reddish purple. Should the blue colour remain unchanged, test it with yellow turmeric or reddened litmus paper; if the urine is alkaline,—owing, probably, to the conversion of urea into carbonate of ammonia (11),—the turmeric will become brown, and the reddened litmus blue; while, if the colour in both cases remains unaltered, the urine may be considered neutral.

278. The specific gravity of the urine may then be taken. This is most readily done by means of the urinometer, which is a little instrument constructed on the principle of the hydrometer, the usual form of which is shown in the annexed figure. The tube, when used, is simply immersed in the urine, and when it has come to rest, the number on the graduated scale, which stands at the level of the liquid, when added to 1000, will represent the specific gravity of the fluid. For example, if the level of the liquid stands at 5 on the scale, the specific gravity of the urine will be 1005; if at 30, it will be 1030, and so on (301). If an urinometer is not at hand, the specific gravity of the urine may be taken by means of a bottle, or even with a lump of glass (Prac. Chem. 148, 149).

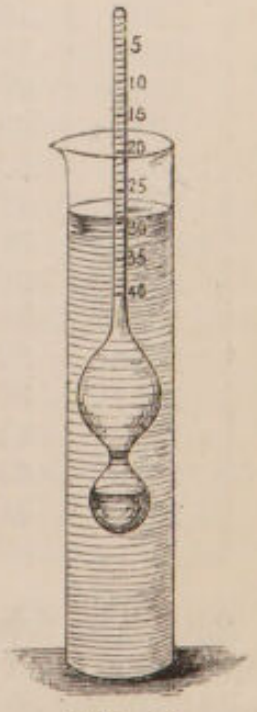

Fig. 36.

279. It is often a matter of some importance to the physician, to be able to determine the amount of solid matter which is excreted daily from the body, through the kidneys. If the weight of the whole quantity of urine passed during the twenty-four hours is ascertained, and also the specific gravity of the whole of it when mixed together, we can, by reference to the following table, learn, with a sufficient degree of accuracy for most purposes, the weight of solid matter contained in it.

TABLE,

Showing the Amount of Solid Matters and of Water in urine of different specific gravities. (Dr. G. Bird.)

Specific gravity.	Grains of solid matter in 1000 grs. of urine.	Grains of water in 1000 grs. of urine.	Specific gravity.	Grains of solid matter in 1000 grs. of urine.	Grains of water in 1000 grs. of urine.
1001	2.33	997.67	1021	48.93	951.07
1002	4.66	995.34	1022	51.26	948.74
1003	6.99	993.01	1023	53.59	946.41
1004	9.32	990.68	1024	55.92	944.18
1005	11.65	988.35	1025	58.25	941.75
1006	13.98	986.02	1026	60.58	939.42
1007	16.31	983.69	1027	62.91	937.09
1008	18.64	981.36	1028	65.24	934.76
1009	20.97	979.03	1029	67.57	932.43
1010	23.30	976.70	1030	69.90	930.10
1011	25.63	974.37	1031	72.23	927.77
1012	27.96	972.04	1032	74.56	925.44
1013	30.29	969.71	1033	76.89	923.11
1014	32.62	967.38	1034	79.22	920.78
1015	34.95	965.05	1035	81.55	918.45
1016	37.28	962.72	1036	83.88	916.12
1017	39.61	960.39	1037	86.21	913.79
1018	41.94	958.06	1038	88.54	911.46
1019	44.27	955.73	1039	90.87	909.13
1020	46.60	953.40	1040	93.20	906.80

280. The following table, showing the weight of a pint, and of a fluid ounce, of urine, of the different specific gravities most commonly met with, will probably also be

found useful; since it is generally easier to measure the quantity of urine passed during the day, than to weigh it. It will be seen that a curious coincidence exists between the weight of solid matter contained in a fluid ounce of urine, and the last two of the four figures which represent the specific gravity, both numbers being in most cases nearly identical. This affords a ready and tolerably accurate means of reckoning the quantity of solids contained in the day's urine, which may be known by multiplying the last two figures of the specific gravity, by the number of fluid ounces of urine passed during the twenty-four hours. Thus, if the specific gravity is found to be 1025, and the quantity passed 46 ounces, the amount of solid matter contained in it will be very nearly 25×46, or 1150 grains.

TABLE,

Showing the Weight of a Pint, and of a Fluid Ounce, of urine of different specific gravities; and also the Weight of Solid Matter in each Fluid Ounce. (Dr. G. Bird.)

Specific gravity of urine.	Weight of one pint.	Weight of one fluid ounce.	Weight of solid matter in one fluid ounce.	Specific gravity of urine.	Weight of one pint.	Weight of one fluid ounce.	Weight of solid matter in one fluid ounce.
	Grains.	Grains.	Grains.		Grains.	Grains	Grains.
1.010	8837	441.8	10.28	1.023	8951	447.5	23.98
1.011	8846	442.3	11.33	1.024	8960	448.0	25.05
1.012	8855	442.7	12.37	1.025	8968	448.4	26.12
1.013	8863	443.1	13.42	1.026	8977	448.8	27.18
1.014	8872	443.6	14.47	1.027	8986	449.3	28.26
1.015	8881	444.0	15.52	1.028	8995	449.7	29.33
1.016	8890	444.5	16.57	1.029	9003	450.1	30.41
1.017	8898	444.9	17.62	1.030	9012	450.6	31.49
1.018	8907	445.3	18.67	1.031	9021	451.0	32.57
1.019	8916	445.8	19.73	1.032	9030	451.5	33.66
1.020	8925	446.2	20.79	1.033	9038	451.9	35.75
1.021	8933	446.6	21.85	1.034	9047	452.3	35.83
1.022	8942	447.1	22.91	1.035	9056	452.8	36.92

281. The deposit may now be for the most part separated from the urine, by allowing it to subside for a short time,

and then pouring off the clear liquid. The portion of urine containing the sediment in suspension may be first examined. For the mode of examining the clear liquid separated from it, see paragraphs 300 to 314.

Examination of the Solid Deposit.

282. If, owing to some characteristic peculiarity in the appearance of the deposit, or of the urine containing it, or from other circumstances, the observer has reason to suspect the nature of the sediment, he may at once proceed to apply the tests for the suspected substance, according to the directions given in Chapter V., page 55. At first, however, and until he has had some little experience on the subject, he will do well to adopt some such method of examination as the following.

283. In the great majority of cases, the deposits contained in urine will be found to consist of one or other of the following substances—viz., earthy phosphates, uric acid, urate of ammonia, or oxalate of lime; sometimes alone, sometimes two or more mixed with each other, or with mucus or other matters. The first experiments, therefore, should be directed to the detection of these four substances.

284. Put a little of the urine containing the deposit, in a test tube, and warm it gently over a lamp. IF IT READILY DISSOLVES, it is probably URATE OF AMMONIA (192); in which case one or two of the more characteristic tests for that substance may be applied, and the deposit may be examined under the microscope; in order to confirm or correct the first result (91, 194, 197). If purpurine is present with the urate, which may be known by its pink or reddish colour, the deposit will probably not dissolve so immediately on warming, as when the colouring matter is absent (192). If the deposit does not dissolve when gently warmed, nor yet when heated nearly to boiling, it must be further tested as follows (285).

285. IF THE DEPOSIT DOES NOT DISSOLVE WHEN WARMED, add to a few drops of the sedimentary urine in a test tube, a little acetic acid.

286. If the DEPOSIT DISSOLVES IN ACETIC ACID, it probably consists of EARTHY PHOSPHATES, the nature of which, whether consisting of phosphate of lime, or triple

phosphate, or a mixture of both, may be distinguished by submitting a little of the deposit to microscopic examination (228, 317, 322). (Confirm 47, 225—227.)

287. IF THE DEPOSIT PROVES INSOLUBLE IN ACETIC ACID, test another portion with a little dilute hydrochloric acid. If it DISSOLVES IN THE ACID, and the acid solution thus obtained gives, when neutralized with ammonia, a white precipitate, it is probably OXALATE OF LIME (266). (Confirm 319, 266, 267.)

288. IF THE HYDROCHLORIC ACID FAILS TO DISSOLVE THE DEPOSIT, it may be tested for URIC ACID by means of nitric acid and ammonia, in the manner described in paragraph 23. Uric acid may also be readily distinguished under the microscope (318). (Confirm 187, 188.)

289. If the deposit proves to consist neither of earthy phosphates, uric acid, urate of ammonia, nor oxalate of lime, it must be examined for the other matters which are occasionally, though less frequently, met with in morbid urine, and which have been already noticed in Chapters IV. & V. It must be remembered, that in perhaps the majority of cases, urinary deposits do not consist *exclusively* of any one substance, but contain two or more mixed together; as when the earthy phosphates occur associated with an excess of mucus. The action of the several tests may frequently in this way be more or less masked, and when taken alone, may lead to erroneous conclusions. In such cases, the microscope will be found of infinite value, and should always, when available, be employed (315).

290. If the deposit sinks readily to the bottom of the vessel, forming a PALE GREENISH YELLOW SEDIMENT, which, on agitation, is again diffused readily and uniformly in the liquid, it probably consists of PUS (247). (Confirm 250, 254, 256, 257, 156.)

291. If, on the other hand, the deposit is TENACIOUS AND ROPY, not mixing uniformly with the liquid when shaken, it probably contains an excess of MUCUS (210). (Confirm 211, 100, 156.)

292. If the deposit is DARK COLOURED, brown, or red, and has been found not to consist of urate of ammonia coloured with purpurine (284), it probably contains BLOOD; in which case the clear portion of the urine (281) will give indications of albumen when heated, or when tested with nitric acid (243). (Confirm 240, 242, 245.)

293. When the deposit is WHITE, OR NEARLY SO, having proved insoluble when warmed (284), and also when treated with dilute hydrochloric and acetic acids (285, 286); and is found to be readily SOLUBLE IN A SOLUTION OF AMMONIA, the ammoniacal solution yielding on evaporation, HEXAGONAL CRYSTALLINE PLATES; it is probably CYSTINE (272, 270, 273).

294. If the deposit is PALE YELLOW, tolerably soluble when warmed (200), but does not appear to consist of urate of ammonia, owing to its yielding no traces of ammonia when warmed with a solution of potash (205), and appearing under the microscope not as an amorphous sediment, but in small irregularly shaped roundish or oval particles, with or without projecting protuberances (324), it is probably URATE OF SODA. (Confirm 202, 203, 204.)

295. If, when a little of the urine is agitated with a few drops of ether in a test tube, and the etherial solution, after separating from the watery portion on which it floats, is found to leave, after evaporation at a gentle heat, a residue of fat or oily matter, the presence of FAT may be inferred (259). (Confirm 325.)

296. If the urine is OPAQUE AND ALMOST MILKY in appearance, yielding traces of fat when treated with ether, and is found, when examined under the microscope, to contain an abundant white amorphous or granular deposit of albumen, together probably with small round colourless corpuscles, it probably contains CHYLOUS MATTER (260). (Confirm 261, 326.)

297. If, on examination under a microscope of high magnifying power, minute ANIMALCULES are visible, having the appearance shown in figure 22, page 50, it is probable that SEMEN is present (160). (Confirm 161, 264.)

298. The following Table may serve to facilitate the examination of deposits with reagents. It must, however, be borne in mind, that until the observer has had some little experience in the action of the several tests, he must not depend too much on the result of any one experiment; but must in all cases confirm his suspicions by one or more corroborative tests.

TABLE

For facilitating the Examination of Urinary Deposits, by means of Chemical Tests.

299. Test first for the earthy phosphates, uric acid, urate of ammonia, and oxalate of lime (283).

1. THE SEDIMENT DISSOLVES WHEN WARMED. *Urate of ammonia* (284). NOT SOLUBLE WHEN WARMED. See 2.
2. SOLUBLE IN ACETIC ACID. *Earthy phosphates* (286). INSOLUBLE IN ACETIC ACID. See 3.
3. SOLUBLE IN DILUTE HYDROCHLORIC ACID. *Oxalate of lime* (287). INSOLUBLE IN DILUTE HYDROCHLORIC ACID. See 4.
4. PURPLE, WITH NITRIC ACID AND AMMONIA. *Uric acid* (288).

If the deposit proves to be neither of the above, it must be one of the following:—

5. GREENISH YELLOW DEPOSIT, EASILY DIFFUSED ON AGITATION. *Pus?* (290).
6. ROPY AND TENACIOUS. *Mucus?* (291).
7. RED OR BROWN; NOT SOLUBLE WHEN WARMED; THE FLUID PORTION COAGULABLE BY HEAT AND NITRIC ACID. *Blood?* (292).
8. SOLUBLE IN AMMONIA; THE SOLUTION LEAVING, ON EVAPORATION, HEXAGONAL CRYSTALS. *Cystine?* (293).
9. YELLOWISH SEDIMENT, SOLUBLE WHEN WARMED. *Urate of Soda?* (294).
10. ETHER YIELDS, AFTER AGITATION, AN OILY OR FATTY RESIDUE. *Fatty matter* (295).
11. MILKY APPEARANCE. *Chylous matter* (296).

SECTION II.

Examination of Urine containing no Solid Deposit; or from which a Deposit has been separated (281).

300. Test the urine with litmus and turmeric paper (277).* If ALKALINE, it must be tested for ALBUMEN with nitric acid (305, 306).

301. Take the specific gravity (278).* If the SPECIFIC GRAVITY IS HIGHER THAN 1025, the urine may perhaps be found to contain either SUGAR or an EXCESS OF UREA (302, 304). If the specific gravity is not higher than 1025, pass on to 305. See also 304.

302. Whether UREA be present in excess, may be ascertained by mixing a little of the urine, in a watch glass or test tube, with an equal bulk of pure nitric acid, keeping the glass cool by allowing it to float in cold water. If any excess of urea is present, a more or less abundant crop of crystals of nitrate of urea will, in a short time, appear in the mixture (181). (Confirm 183.)

303. When a microscope is at hand, we can in this manner detect even a very slight excess of urea. A drop of the suspected urine is placed on a slip of glass, and mixed with a drop of pure nitric acid. If even a small excess of urea is present, minute crystals of the nitrate may generally be seen, after a short time, with a very moderate magnifying power.

304. To prove the presence of SUGAR, a little of the urine may be examined by means of Trommer's test (122), and the fermentation test (127). (Confirm 132.) It must here be borne in mind, that very decided traces of sugar may exist in urine without raising the density to a suspicious extent; so that the mere circumstance of the specific gravity of the urine being below 1025, is no proof whatever of the absence of sugar; and in any doubtful case it should be carefully looked for by means of the tests above referred to.

305. Boil a little of the urine in a test tube. If the liquid

* If these experiments had been already made before the separation of the sedimentary and non-sedimentary portions of the urine (281), they need not be repeated.

remains clear, pass on to 307; but if a PRECIPITATE IS PRODUCED, it may be owing to the presence either of albumen (235), or of an excess of earthy phosphates (109). To distinguish between them, add to the boiled portion a few drops of nitric acid. If the PRECIPITATE DISSOLVES, and is not reprecipitated by the addition of a few more drops of the acid, it probably consists of EARTHY PHOSPHATES (229). (Confirm 228, 226;) while, if it either does not dissolve, or after being dissolved by the first drop or two of the acid, again precipitates when the liquid is more strongly acidified, ALBUMEN is indicated (143). (Confirm 137, 138.)

306. It must be remembered that when the urine is alkaline, ALBUMEN may be present in it without being coagulated by boiling (142). Such urine should therefore be tested for albumen, by means of nitric acid (141).

307. Add to a little of the suspected urine a few drops of nitric acid. If a PRECIPITATE IS PRODUCED, either immediately or after a short time, none having been occasioned by boiling (305), an EXCESS OF URIC ACID is probably present (190). (Confirm 23, 288.) If the urine is alkaline, the precipitate thus occasioned may consist of ALBUMEN, since that substance would not then be precipitated by boiling (306).

308. Evaporate a little of the urine on a water bath, to the consistence of a syrup, and add about half its bulk of strong hydrochloric acid. If, after the lapse of a few hours, tufts or branches of NEEDLE-SHAPED CRYSTALS are visible, either to the naked eye, or when examined under the microscope, an excess of HIPPURIC ACID is probably present (206). (Confirm 208, 209.)

309. If THE URINE IS HIGHLY COLOURED, it is probable, either that it contains an excess of yellow-colouring matter, or that blood, biliary matter, or purpurine, is present. To determine which of these it is,

310. Boil a little of the urine; if it contains BLOOD, the albumen will COAGULATE, mixed with some of the colouring matter (243). (Confirm 240, 245.)

311. If an excess of YELLOW COLOURING MATTER is present, the boiled urine, when mixed with a little hydrochloric acid, will assume a more or less decided RED COLOUR (215).

312. The presence of biliary matter may be proved by Pettenkofer's and Heller's tests (149, 151). (Confirm 152.)

313. If PURPURINE is present in solution, the urine usually has a more or less decided pink colour; and when a little warm aqueous solution of urate of ammonia is mixed with it, that salt precipitates as the liquid cools, and carries with it nearly the whole of the purpurine, which gives the precipitate a PINK COLOUR (221). (Confirm 218, 220.)

314. The following table may be found useful for reference (298).

TABLE

For facilitating the Examination of the clear liquid portion of Urine, by means of Tests.

1. SPECIFIC GRAVITY HIGHER THAN 1025. See 2 & 3.
2. CRYSTALS WITH NITRIC ACID. *Excess of urea* (302).
3. FERMENTATION OR TROMMER'S TEST. *Sugar* (304).
4. IF NEUTRAL OR FEEBLY ACID TO TEST PAPER, see 5, &c. IF ALKALINE, see 7.
5. PRECIPITATE FORMED ON BOILING; SOLUBLE IN NITRIC ACID. *Excess of earthy phosphates* (305).
6. PRECIPITATE FORMED ON BOILING; INSOLUBLE IN NITRIC ACID. *Albumen* (305).
7. PRECIPITATE FORMED BY NITRIC ACID. *Excess of uric acid*, or *albumen* (307).
8. CONCENTRATED URINE YIELDS NEEDLE-SHAPED CRYSTALS WITH HYDROCHLORIC ACID. *Hippuric acid* (308).
9. IF THE URINE IS HIGHLY COLOURED, see 10, 11, 12, & 13.
10. DARK COAGULUM FORMED ON BOILING. *Blood?* (310).
11. RED COLOUR WITH HYDROCHLORIC ACID. *Excess of colouring matter* (311).

12. PINK PRECIPITATE WITH WARM SOLUTION OF URATE OF AMMONIA. *Purpurine* (313).

13. CHANGE OF COLOUR WITH NITRIC ACID, &c. *Biliary matter* (152, 312).

SECTION III.

Microscopic examination of Urinary Deposits (276, 289).

315. Place a drop of the urine containing the deposit (after being allowed to stand a short time, that the sediment may subside) on a strip of glass; cover it with a small square of thin glass, and examine it with a magnifying power of about two hundred diameters. Observe whether the particles are CRYSTALLINE, AMORPHOUS, or ORGANIZED. If CRYSTALLINE, refer to paragraph 316; if AMORPHOUS, to paragraph 321; and if ORGANIZED, pass on to paragraph 327. When, as is frequently the case, the deposit appears to consist of a mixture of two or more different forms of matter, each of these should in succession be examined, until the nature of the whole of the deposit is clearly understood.

316. IF THE DEPOSIT IS CRYSTALLINE, it is probably either URIC ACID, TRIPLE PHOSPHATE, or OXALATE OF LIME; or possibly CYSTINE.

317. If the crystals are STELLATE (Fig. 37), or TRIANGULAR PRISMS (Fig. 38), instantly disappearing on the addition of acetic acid, they consist of the TRIPLE PHOSPHATE. (Confirm 286.)

318. IF THE CRYSTALS ARE LOZENGE-SHAPED, OR POSSESS ANY OF THE FORMS SHOWN IN FIGURE 39, being insoluble in dilute acids, but tolerably soluble in a solution of potash, they are probably uric acid. (Confirm 288.)

319. If the crystals are OCTOHEDRA (Fig. 40), or some modification of the DUMB-BELL form (Fig. 41), insoluble in acetic acid, but readily soluble in dilute hydrochloric acid, they are probably OXALATE OF LIME. (Confirm 287.)

320. If the crystals are MULTANGULAR PLATES, having the rosette-like form shown in figure 42, insoluble, or nearly so, in water and dilute acids, but readily soluble in

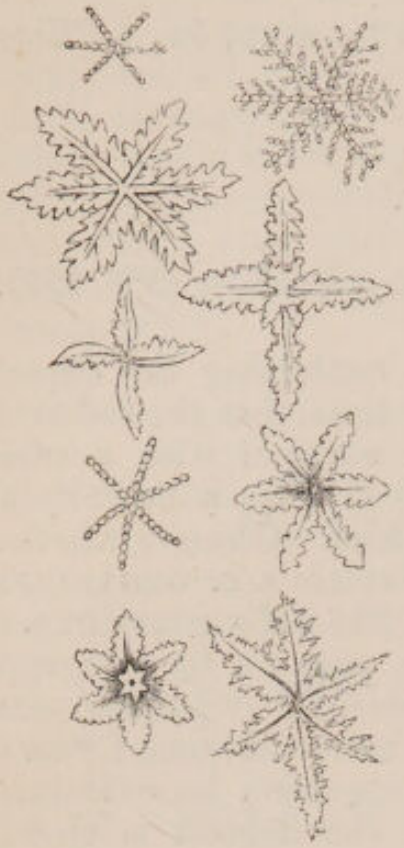

Fig. 37.

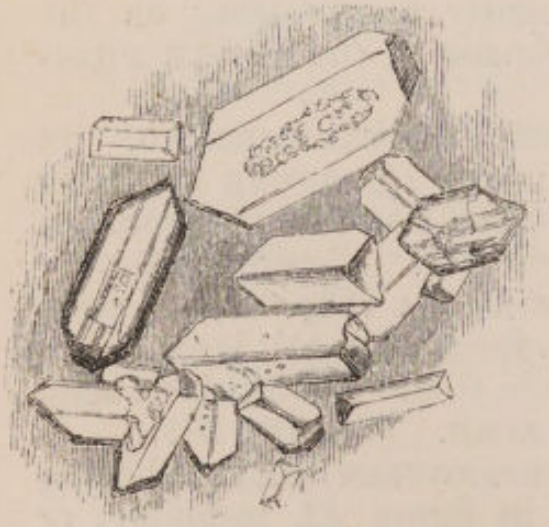

Fig. 38.

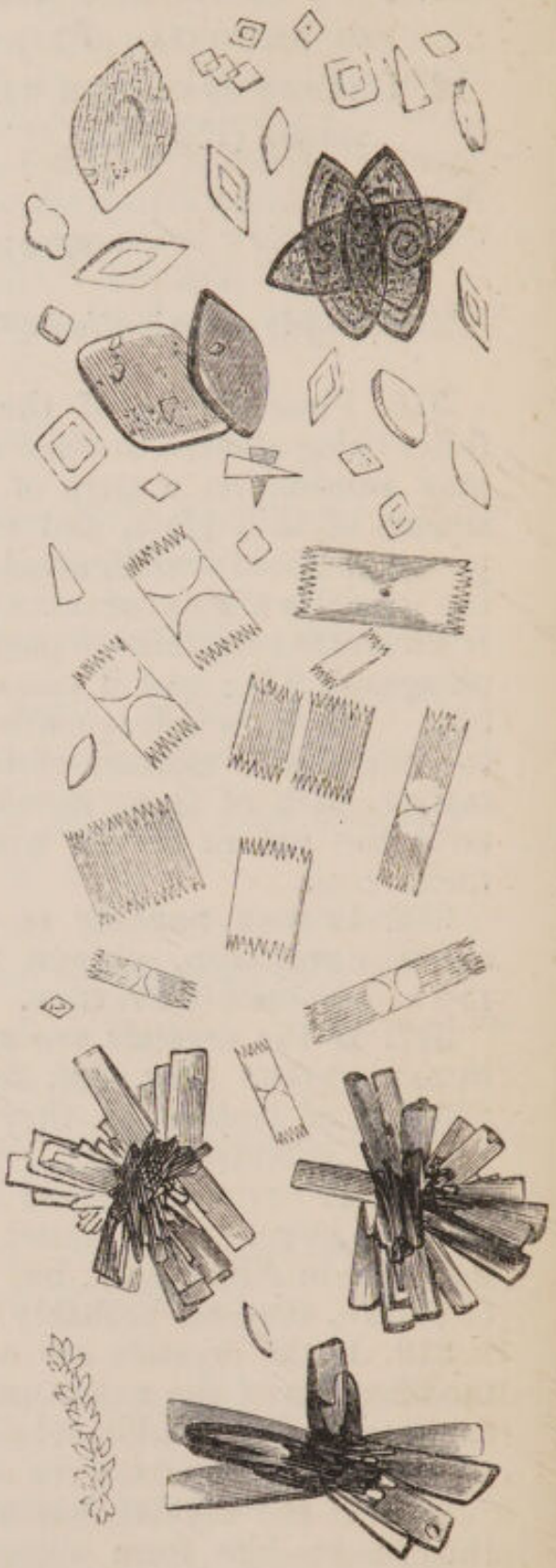

Fig. 39.

Fig. 40.

Fig. 41.

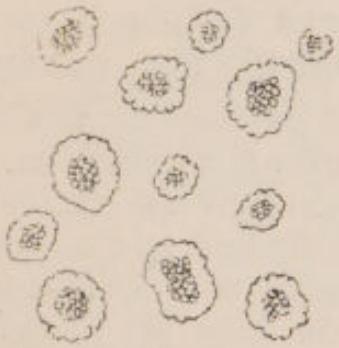

Fig. 42.

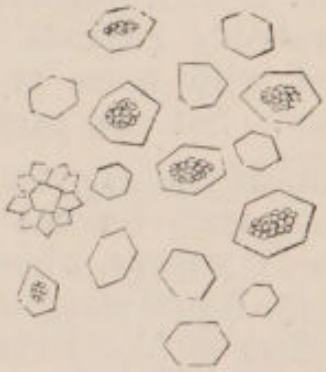

Fig. 43.

ammonia, the ammoniacal solution leaving, on evaporation, HEXAGONAL CRYSTALLINE PLATES (Fig. 43), they are probably CYSTINE (293).

321. IF THE DEPOSIT IS AMORPHOUS, OR IN MINUTE ROUNDED PARTICLES, it probably consists of PHOSPHATE OF LIME, or URATE OF AMMONIA; or possibly URATE OF SODA, FAT, or CHYLOUS MATTER. See also 327, &c.

322. If it is INSOLUBLE WHEN WARMED, but DISSOLVES IMMEDIATELY on the addition of ACETIC OR DILUTE HYDROCHLORIC ACID, it is probably PHOSPHATE OF LIME (228). (Confirm 47, 225—227.)

323. If it DISSOLVES READILY when the urine containing it IS WARMED, and is again DEPOSITED ON COOLING, it is probably URATE OF AMMONIA. (Confirm 284.)

324. If the deposit is in the form of PALE YELLOWISH GRAINS, with or without small irregular protuberances

(Fig. 44), DISSOLVING more or less readily WHEN WARMED, but not consisting of urate of ammonia, it is probably URATE OF SODA. (Confirm 294.)

325. If the substance is in the form of MINUTE ROUND GLOBULES, WITH DARK AND WELL-DEFINED OUTLINES (Fig. 45), and DISSOLVES WHEN AGITATED WITH ETHER, it probably consists of FATTY MATTER. (Confirm 295.)

326. If the urine is OPAQUE AND MILKY in appearance, yielding fatty matter when agitated with ether, and containing minute amorphous albuminous particles, and perhaps also colourless globules, it probably contains CHYLOUS MATTER. (Confirm 296.)

327. IF THE DEPOSIT CONSISTS OF ORGANIZED PARTICLES, it probably consists either of MUCUS (which is usually mixed with more or less EPITHELIUM), PUS, BLOOD, or SEMEN. See also paragraph 132.

328. If the PARTICLES ARE ROUND, OR NEARLY SO, AND GRANULATED on the surface, ENTANGLED IN TENACIOUS STRINGY MASSES, which do not break up and mix uniformly with the liquid on agitation, it is probably MUCUS (Fig. 46, *a*). (Confirm 291.) EPITHELIAL DEBRIS may be recognised by the peculiar forms of its particles (Fig. 46, *b*.) (156.) Mucous urine very generally contains also a considerable amount of earthy phosphates and other matters (211).

329. If the particles are ROUND AND GRANULAR (Fig. 47), not being held together by any tenacious matter, but FLOATING FREELY IN THE LIQUID, the deposit probably consists of PUS. (Confirm 290, 156.)

330. If the particles appear as CIRCULAR AND SLIGHTLY CONCAVE DISCS, the outlines being occasionally irregular (Fig. 48), and of a more or less decided yellowish colour, it is probable that BLOOD is present. (Confirm 290.)

331. If the particles, or any among them, have the form of seminal animalcules, or SPERMATOZOA, shown in figure 49, SEMEN is probably present. (Confirm 297.)

332. The Table on page 92 may be useful to the student for reference, in the microscopical examination of urinary deposits.

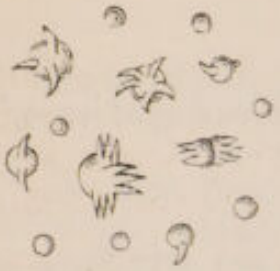

Fig. 44.

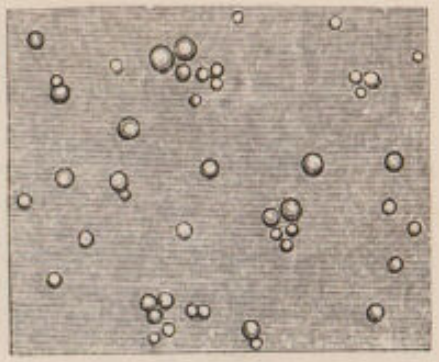

Fig. 45.

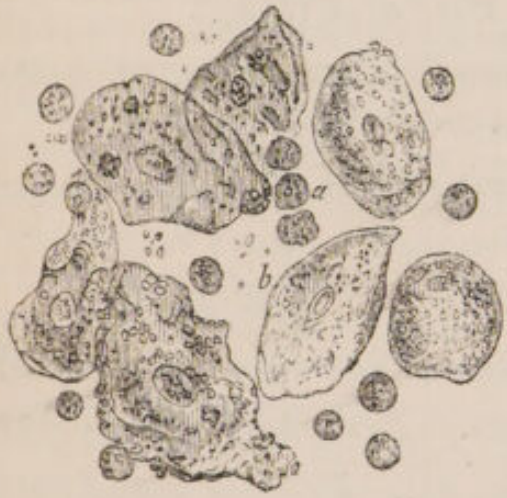

Fig 46

Fig. 47.

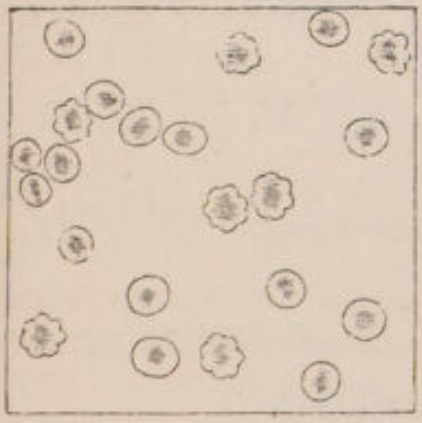

Fig. 48.

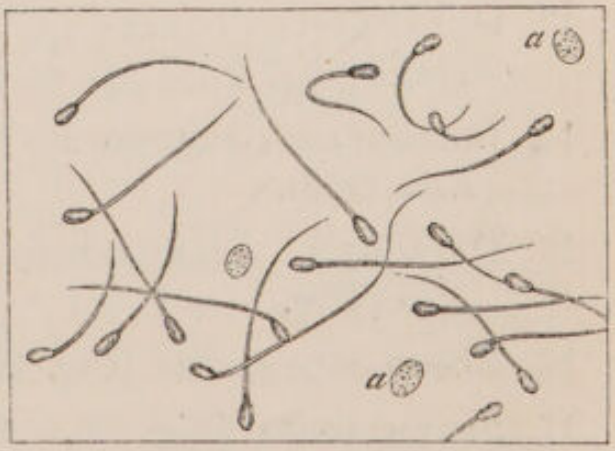

Fig. 49.

TABLE

For facilitating the Microscopical Examination of Urinary Deposits.

1. If the deposit is crystalline, see 4 to 7.
2. If amorphous, or rounded particles, see 8 to 12.
3. If organized particles, see 13 to 17.
4. Lozenge-shaped crystals, and other forms shown in figure 39. *Uric acid* (318).
5. Stellæ, or three-sided prisms (Figs. 37 & 38). *Triple phosphate* (317).
6. Octohedra, or dumb-bells (Figs. 40 & 41). *Oxalate of lime* (319).
7. Rosette-like tables (Fig. 42). *Cystine* (320).
8. Soluble when warmed. *Urate of ammonia* (323).
9. Soluble in acetic acid. *Phosphate of lime* (322).
10. Yellowish grains (Fig. 44). *Urate of soda?* (324).
11. Round globules with dark edges (Fig. 45). *Fatty matter* (325).
12. White and milky. *Chylous matter?* (326).
13. Granulated corpuscles, in stringy aggregations (Fig. 46). *Mucus* (328).
14. Irregularly-shaped scales (Fig. 46, *b*). *Epithelium* (328).
15. Detached granulated corpuscles (Fig. 47). *Pus* (329).
16. Blood-corpuscles (Fig. 48). *Blood* (330).
17. Spermatozoa (Fig. 49). *Semen* (331).

CHAPTER VII.

QUANTITATIVE ANALYSIS OF DIABETIC URINE.

333. In the quantitative examination of diabetic urine, it is generally sufficient to estimate merely the quantity of sugar, since the determination of the other constituents is of comparatively small practical importance in diagnosis. When this is the case, all that is necessary is, to ferment 250 grains of the urine in the manner described below (336); and from the amount of carbonic acid evolved, to estimate the quantity of sugar which yielded it.

334. It is, however, frequently of importance to be able to determine the proportion of some of the other matters co-existing in the urine, especially the urea (119), which has been supposed by some to diminish, and by others to increase, materially in quantity, simultaneously with the appearance of sugar. The exact estimation of small quantities of urea, when mixed, as in diabetic urine, with a large amount of sugar, is attended with considerable practical difficulty; and, indeed, the results hitherto obtained must be regarded merely as approximations to the truth. By the method of analysis which I am about to describe, the proportions of the following substances may, without much difficulty, be determined; or the inquiry may be limited to the estimation of the sugar and urea (335, 341):—1, water; 2, sugar; 3, urea; 4, uric acid and vesical mucus; 5, animal extractive and ammoniacal salts; 6, fixed alkaline salts; and 7, earthy salts.

335. Two portions of the urine, A weighing 1000 grains, and B weighing 500 grains, are to be evaporated to dryness (50), in weighed or counterpoised dishes, on a water or chloride-of-calcium bath; or still better, in vacuo over sulphuric acid (Prac. Chem. 646). While the evaporation of A and B is going on, a third portion C, consisting of 250 grains of the urine, may be weighed out, for the purpose of estimating the sugar, which is done in the following manner (336).

336. *Treatment of the portion C.*—Put 250 grains of the urine into a small wide-mouthed bottle, capable of holding an ounce and half, or two ounces of water; to the mouth

of which is adapted a cork, fitted with tubes of the form shown in the figure (Fig. 50). The bottle should be graduated in cubic inches and tenths, in order to enable the experimenter to estimate the amount of carbonic acid which is retained in solution by the liquid, at the close of the operation (338). The tube *a* is nearly filled with small fragments of dry chloride of calcium, which are prevented from falling out, by a loose plug of cotton wool placed at each end. The tube *b*, which reaches nearly to the bottom, is made open at both ends; the top, however, being accurately closed by means of a small bit of cork or wax, *c*, during the process of fermentation.

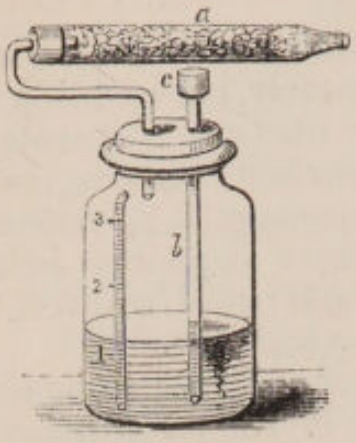

Fig. 50.

337. Mix a few drops of fresh yeast, or still better, about fifty grains of dry German yeast (128), with the urine in the bottle; and having placed the cork, with its tubes, firmly in the neck, weigh the whole apparatus with its contents as accurately as possible. Allow the apparatus to stand a day or two in a warm place, having a temperature of about 70° or 80°; and when the fermentation appears to have entirely ceased, remove the small plug of cork or wax from the tube *b*, and blow air gently down it, for the purpose of expelling the carbonic acid contained in the bottle, and replacing it with common air. The small plug is then attached to the tube *b* as before, and the whole apparatus is again weighed.

338. The amount of loss will indicate the quantity of carbonic acid which has escaped through the tube *a*; but as carbonic acid is soluble, at ordinary temperatures, in about its own bulk of water, the portion of acid held in solution by the liquid, must be added to that which has escaped. This amount is readily known, since each cubic inch of liquid, which may be supposed to be saturated with the acid, must contain about a cubic inch of the gas, weighing rather less than half a grain.*

* One hundred cubic inches of carbonic acid weigh 47.26 grains; one cubic inch, consequently, weighs 0.47 of a grain.

339. The whole amount of carbonic acid formed during fermentation, therefore, is determined by adding to the loss of weight, half a grain for every cubic inch of liquid contained in the bottle, the quantity of which is known by the graduations on the surface (336). Thus, supposing the loss of weight during fermentation to have been 4.1 grains, and the volume of liquid in the bottle 1.2 cubic inch, the weight of the carbonic acid formed must be $4.1 + \frac{1.2}{2}$, or 4.7 grains.

340. Now, since every equivalent of diabetic sugar ($C_{12}H_{14}O_{14}$) is converted, during fermentation, into two equivalents of alcohol (C_4H_5,O,HO), four equivalents of carbonic acid (CO_2), and two equivalents of water (HO);

$$C_{12}H_{14}O_{14}=2(C_4H_5,O,HO)+4CO_2+2HO;$$

it follows that every 198 parts by weight of sugar (one equivalent), give rise to the formation of 88 parts of carbonic acid (four equivalents); so that every 88 grains of carbonic acid would indicate 198 grains of sugar; or in other words, one grain of carbonic acid will represent 2.25 grains of sugar. Therefore, by multiplying the weight of carbonic acid by 2.25, we obtain the weight of SUGAR present in the quantity of urine operated on. Thus, in the above example, 4.7 grains multiplied by 2.25 (= 10.57), gives the weight of sugar in 250 grains of urine; which, when multiplied by four ($250 \times 4 = 1000$), represents the proportion in 1000 grains of the secretion.

341. *Treatment of the portion A.*—The dry residue left after the evaporation of the 1000 grains marked A (335), is to be used for estimating the urea, which is usually present only in minute proportion in diabetic urine. For this purpose, the residue is treated with successive small quantities of alcohol, stirring the mixture with a glass rod, until it ceases to dissolve anything more. The alcoholic solution is now to be evaporated to dryness on a water bath, and the residue treated with strong alcohol (absolute alcohol if possible, 114), which will dissolve out the urea, leaving undissolved most of the sugar and other matters. The alcoholic solution thus obtained is to be again evaporated to dryness on a water bath, and the residue treated, as long as anything dissolves, with warm distilled water, which will separate the urea from most of the other matters which are less soluble in water.

342. The impure aqueous solution of urea thus obtained, is evaporated to a small bulk, and while at a temperature of about 190° or 200°, mixed with as much pounded oxalic acid (HO,C_2O_3+3Aq) as will dissolve in the liquid (14). The mixture, after cooling, is immersed in a freezing mixture;* when the whole of the oxalate of urea, together with the excess of oxalic acid, will crystallize out. The liquid is now to be poured off, and the crystals gently pressed between folds of filtering paper, in order to remove as much as possible of the soluble impurities contained in the water. The crystals are to be redissolved in warm water, and the solution thus obtained, mixed and well stirred with finely pounded carbonate of lime (CaO,CO_2) as long as any effervescence occurs; by which means the oxalic acid is separated from the urea, which remains uncombined in the solution (8). After filtering, the aqueous solution, containing the urea, is placed in a small weighed or counterpoised dish, evaporated to dryness on a water bath, or in vacuo over sulphuric acid, and accurately weighed; when its weight will represent the proportion of UREA in 1000 grains of the urine.

343. *Treatment of the portion B.*—The residue left after the evaporation of the 500 grains of urine marked B, may now be examined, for the purpose of estimating, 1, the water; 2, uric acid and vesical mucus; 3, animal extractive and ammoniacal salts; 4, fixed alkaline salts; and 5, earthy salts. For this purpose it is to be carefully evaporated until it ceases to lose weight, either on a water or chloride-of-calcium bath, or still better, in vacuo over sulphuric acid; since by long exposure to a high temperature, a portion of the sugar loses five equivalents of water, and becomes converted into a kind of uncrystallizable caramel, thus causing the residue to weigh less than it ought to do. It is generally a matter of considerable difficulty to expel the last traces of water from the residue of diabetic urine: for ordinary purposes, however, this is not of much importance, since the small error which it here occasions affects only the proportion of the water and animal extractive, and not that of the two substances of most importance—viz., the sugar and the urea.

* A little pounded ice or snow, mixed with about half its weight of common salt; or, in the absence of ice, a mixture of equal weights of nitrate of ammonia and water, will be found the most convenient freezing mixture.

344. The dry residue B is to be weighed; and by deducting its weight from that of the urine before evaporation (500 grains), the proportion of water is determined; which when multiplied by two ($500 \times 2 = 1000$), gives the proportion of WATER in 1000 grains of the secretion.

345. The weight of the dry residue having been carefully noted, it is to be treated with boiling water as long as anything appears to dissolve. In this way, the sugar, urea, animal extractive, and alkaline salts are dissolved out, leaving a small insoluble residue, consisting of vesical mucus, uric acid, earthy phosphates, and traces of silica.

346. The aqueous solution thus formed, is to be evaporated to dryness on a water bath, and retained for subsequent experiments (349).

347. The weight of the matter insoluble in water (345), having been noted after careful drying, it is to be incinerated until the residue becomes white or pale grey. The ash thus obtained is to be weighed; and its weight, multiplied by two, furnishes the proportion of EARTHY SALTS in 1000 grains of the urine.

348. The difference between the weight of the ash, and that of the dry insoluble residue previous to ignition (347), represents the quantity of insoluble organic matter, consisting of URIC ACID and MUCUS in 500 grains of the urine; which must be multiplied by two, as in the former cases, in order to give the proportion in 1000 grains of the secretion.

349. The dry residue obtained by evaporating the aqueous solution (346), consisting of the soluble matters of the urine, is now to be weighed. It consists of two portions, the organic or combustible, and the inorganic or incombustible. The relative amounts of these two portions are determined by incineration; the weight of the ash representing the FIXED ALKALINE SALTS in 500 grains; which, as before, is to be multiplied by two.

350. The loss of weight experienced during incineration (349), which is that of the soluble combustible matters—viz., sugar, urea, animal extractive, and ammoniacal salts, is also to be multiplied by two. Now since we know from our experiments with the other portions of urine A and C, the weight of the sugar and urea (340, 342), we can, by deducting their combined weights from the amount of loss during ignition, obtain the proportion of ANIMAL

EXTRACTIVE and AMMONIACAL SALTS, contained in 1000 grains of the urine.

351. Thus we shall have determined the proportions of the several ingredients of the urine, which together should amount to a fraction less than 1000—viz.,

Water	
Sugar	
Urea	
Uric acid and mucus	
Animal extract and ammoniacal salts	
Fixed alkaline salts	
Earthy salts	
Loss	
	1000.00

352. The following analyses of diabetic urine will serve to illustrate its usual composition.

Analyses I. & II. (*Simon*).

	I.	II.
Specific gravity	1018	1016
Water	957.00	960.00
Solid constituents	43.00	40.00
Urea	traces	7.99
Uric acid	traces	traces
Sugar	39.80	25.00
Extractive matter and soluble salts	2.10	6.50
Earthy phosphates	0.52	0.80
Albumen	traces	traces

Analyses III., IV., & V. (*Dr. Percy*).

	III.	IV.	V.
Specific gravity	1042	1035	1039
Water	894.50	918.30	898.90
Solid constituents	105.50	81.70	101.10
Urea	12.16	30.32	2.39
Uric acid	0.16	0.26	not isolated
Sugar	40.12	17.15	79.10
Extractive matters and soluble salts	53.06	32.59	19.52
Earthy phosphates	...	1.30	0.09

Analysis VI. (*Bouchardat.*)

Water	837.58
Solid constituents	162.42
Urea	8.27
Uric acid	not isolated
Sugar	134.42
Extractive matters and soluble salts	20.34
Earthy phosphates	0.38

CHAPTER VIII.

QUANTITATIVE ANALYSIS OF ALBUMINOUS URINE.

353. In the quantitative analysis of albuminous urine, it is usual to estimate the following ingredients; though for many purposes it is sufficient merely to determine the proportion of albumen, either with or without that of the urea:—1, water; 2, urea; 3, albumen, with traces of uric acid;* 4, vesical mucus; 5, animal extractive and ammoniacal salts; 6, fixed alkaline salts; and 7, earthy salts.

354. *Treatment of the portion A.*—Two portions of the urine, marked respectively A and B, each weighing 500 grains, are to be evaporated to dryness on a water bath.† The portion A will serve for the estimation of the urea; and the portion B for that of the other substances above enumerated.

355. The residue left after the evaporation of A, is treated with hot alcohol, to dissolve out the urea. The alcoholic solution is evaporated to dryness on a water bath, and redissolved, as far as it is capable, in hot distilled water; the aqueous solution thus obtained, is evaporated to a small bulk, and mixed with pounded oxalic acid in the manner described in the analysis of diabetic urine (342). The oxalate of urea is afterwards decomposed by means of car-

* Or the uric acid may be estimated separately; see paragraph 363.

† If it is intended to estimate the uric acid separately, a third portion of urine, weighing 1000 grains, will also be required (363).

bonate of lime in the manner already detailed; the weight of the urea obtained being multiplied by two, in order to represent the proportion of UREA in 1000 grains of the urine.

356. *Treatment of the portion B.*—The residue left after the evaporation of B, is now to be examined. When it has ceased to lose weight by exposure on the water bath, the weight of the residue is to be noted; and the loss which it has sustained during evaporation, multiplied by two, will represent the amount of WATER in 1000 grains of the urine.

357. The dry residue, when cold, is to be carefully reduced to powder in a clean dry mortar, which should be placed on a large sheet of white paper, in order to catch any particles that may be projected out of the mortar during the pounding. The powder is to be boiled with distilled water, which will dissolve out the urea, animal extractive, and soluble salts; leaving an insoluble residue of coagulated albumen, uric acid, mucus, and earthy salts. The mixture is then filtered. The solution thus obtained, we will call M, and the insoluble matter, N.

358. The solution M is to be evaporated to dryness on a water bath, and subsequently examined in the manner described below (361). While the evaporation is going on, the insoluble matter N may be operated on (359).

359. The insoluble matter N, consisting of albumen, uric acid, mucus, and earthy salts, is to be carefully detached from the filter while still moist. It is then warmed for a few seconds with a little dilute nitric acid, (consisting of one part of strong acid and about six parts of water), and well stirred with a glass rod, in order to dissolve out the earthy phosphates. The insoluble portion is to be washed with a little warm water (360), and the acid solution, together with the washings, then evaporated to dryness on a water bath. The dry residue is weighed, incinerated, and weighed again; when the weight of the incombustible matter, multiplied by two, will represent the proportion of EARTHY PHOSPHATES in 1000 parts of the urine; while the loss which the mixture sustained during incineration, also multiplied by two, will represent the amount of VESICAL MUCUS.

360. The portion of N which proved insoluble in the dilute nitric acid (359), consisting of albumen with probably a little uric acid, is to be dried on a water bath, and weighed. The weight, multiplied by two, will represent the propor-

tion of ALBUMEN and URIC ACID in 1000 grains of the urine. This residue should be tested for uric acid, by means of nitric acid and ammonia (23), and if it appears to be present in any considerable quantity, it may be estimated from a separate portion of urine (363).

361. The evaporated residue left by the solution M (358), containing the urea, animal extractive, and soluble salts, must now be examined. After its weight has been ascertained, the dry residue is to be gently ignited, until the incombustible matter becomes white or pale grey. The ash thus obtained is then weighed; and its weight, multiplied by two, will represent the proportion of FIXED ALKALINE SALTS in 1000 grains of the urine.*

362. The loss of weight which the residue sustained during incineration (361) being due to the combustion of the urea and animal extractive, and the volatilization of the ammoniacal salts, derived from 500 grains of urine; we obtain, by doubling it, the amount of those substances contained in 1000 grains. From this we deduct the proportion of urea, which we have already ascertained (355), and the difference will represent the amount of ANIMAL EXTRACTIVE and AMMONIACAL SALTS, contained in 1000 grains of the secretion.

363. If it is required to estimate the proportion of uric acid in albuminous urine, which, however, is seldom necessary, since there is not often more than a small trace of it present, a separate portion of urine must be used for the experiment. For this purpose, one thousand grains are to be boiled for about a quarter of an hour, and filtered from the coagulated albumen. The filtered liquid is then concentrated to about one-fourth its bulk, by evaporation on a water bath, and, after the addition of a few drops of hydrochloric acid, set aside in a cool place for forty-eight hours. The URIC ACID, if present in any notable quantity, will gradually crystallize out, mixed possibly with traces of hippuric acid (25), which may be washed out with a little alcohol (28). The weight of the residue will then, after drying on a water bath, represent the proportion of the acid in 1000 grains of urine.

364. Thus we shall have completed the analysis, having determined the proportion of the several ingredients pro-

* During this ignition, traces of the alkaline chlorides are always volatilized, causing a slight loss.

posed; which when added together, should amount to a fraction less than 1000 grains—viz.,

Water	
Urea	
Albumen	
Uric acid	
Vesical mucus	
Animal extractive and ammoniacal salts	
Fixed alkaline salts	
Earthy salts	
Loss	
	1000.00

365. The following analyses of albuminous urine, in cases of Bright's disease, will serve to show its usual composition.

Analyses I. & II. (Simon).

	I.	II.
Specific gravity	1014	1022
Water	966.10	933.50
Solid constituents	33.90	66.50
Urea	4.77	10.10
Uric acid	0.40	0.60
Fixed salts	8.04	10.00
Extractive matters	2.40	—
Albumen	18.00	33.60

Analysis III. (Dr. Percy.)

Specific gravity	1020
Water	946.82
Solid constituents	53.18
Urea	7.68
Uric acid and indeterminate animal matter	17.52
Fixed soluble salts	5.20
Earthy phosphates	0.14
Albumen	22.64

PART II.

CALCULI AND CONCRETIONS.

CHAPTER I.

URINARY CALCULI.

SECTION I.

366. URINARY calculi are composed, in the great majority of cases, of substances which are contained in healthy urine, such as uric acid, urate of ammonia, and the phosphates of lime and magnesia; they are, however, occasionally composed of substances which are met with only in morbid urine, such as oxalate of lime, cystine, &c. Other substances also, which may strictly be called accidental, are occasionally contained in calculi; such as fragments of sand, or other hard bodies, which have accidentally found their way into the kidneys or bladder, and there formed nuclei, round which the earthy phosphates, or other matters, have gradually been deposited. Calculi always contain, in addition to the ingredients of which they mainly consist, more or less animal matter; such as dried blood and urine, vesical mucus, &c.

367. Calculi are found to consist occasionally almost entirely of one ingredient only, but more frequently of two or more different constituents arranged together in irregular concentric layers. On this account it is impossible to determine, with any degree of certainty, the nature of the mass of a calculus, by merely examining the external coating, since the more central portion may be of a nature wholly different. The best way is to divide the calculus into two equal parts, which is easily done by carefully cutting it through the centre with a fine saw. Fig. 51 represents a mixed calculus

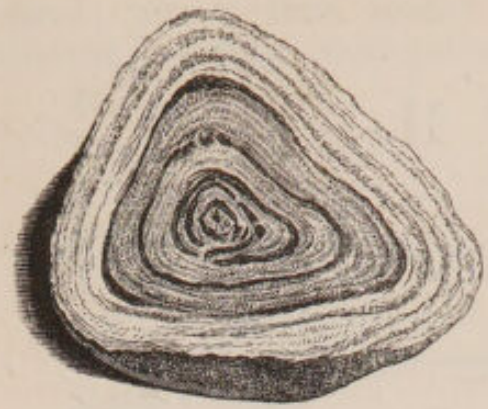

Fig. 51. Alternating calculus.

divided in this manner; the darker layers consisted, in the specimen from which the drawing was made, of oxalate of lime, and the lighter rings, of uric acid. When a calculus is thus found on examination to consist apparently of two or more kinds of matter, fragments of each kind should be carefully detached and separately examined (411).*

SECTION II.

Uric (or Lithic) Acid ($C_{10}N_4H_4O_6$).

368. Uric-acid calculi are usually smooth or slightly tuberculated on the surface (Fig. 52), and of colours varying from pale yellowish fawn, to reddish brown. When sawn through, the layers will generally be found to be tolerably regular, though of different thicknesses, and nearly parallel to the outline of the section. This is the most common of all the urinary calculi.

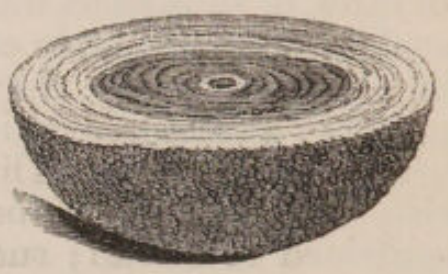

Fig. 52. Uric-acid calculus.

369. Heat a small fragment of the calculus with the blowpipe on platinum foil; it immediately blackens, owing to the charring of the animal matter, emitting at the same time a disagreeable smell, resembling that of burnt feathers, mixed with that of hydrocyanic acid (H,C_2N), which, together with carbonate of ammonia, and some other compounds, is formed during the decomposition. If the heat be continued, the charred residue is gradually consumed, leaving only a slight trace of ash, which is usually alkaline to test paper, consisting of phosphate or carbonate of soda. Traces of the earthy phosphates, also, are almost always to be found in this and most other varieties of calculi.

* A small fragment of the calculus, about the size of a pin's head, is generally sufficient for each experiment, and will be found more convenient in practice than a larger quantity.

370. Uric acid is insoluble in water, and nearly so in dilute acids (22).

371. A little of the calculus in powder is placed in a drop or two of tolerably strong nitric acid, in a watch-glass, or on a strip of glass ; it dissolves with effervescence, carbonic acid and nitrogen being given off, and a mixture of alloxan ($C_8N_2H_4O_{10}$), alloxantine ($C_4H_3N_2O_3$), and some other compounds, remains. This is evaporated nearly to dryness at a gentle heat, when a red residue is left, which, *when cold*, and treated with a drop of ammonia, or exposed to ammoniacal fumes, becomes purple, owing to the formation of murexide ($C_{12}N_5H_6O_8$).

372. Uric acid dissolves in a solution of potash, leaving only a few shreds of animal matter ; and when the mixture is warmed, no smell of ammonia is perceptible, thus differing from the urate of ammonia (377). On neutralizing the alkaline solution with any acid, as hydrochloric, a white precipitate of pure uric acid is thrown down, which, when separated by filtration, may be tested with nitric acid and ammonia, as described in 371.

$$KO,C_{10}N_4H_4O_6+HCl=KCl+HO+C_{10}N_4H_4O_6.$$

373. If the precipitated uric acid be examined under the microscope, it will be found to consist of minute crystals, having the form shown in Fig. 3, page 6.

SECTION III.

Urate (or Lithate) of Ammonia ($NH_4O,C_{10}N_4H_4O_6$).

374. It is not often that we meet with calculi composed wholly of urate of ammonia, that substance being more commonly found alternating with uric acid, earthy phosphates, or other matters. These calculi are generally small in size ; smooth or slightly tuberculated (Fig. 53) ; and pale slate or clay colour, sometimes inclining to brown. The concentric layers are usually thinner, and less distinctly marked, than those of uric acid.

Fig. 53.
Urate-of-ammonia calculus.

375. When heated before the blowpipe, urate of ammonia usually decrepitates, gradually disappears, and in other respects behaves like uric acid (369). It dissolves tolerably well in hot water; but being insoluble, or nearly so, in cold, is deposited again when the solution cools, as an amorphous precipitate. If a dilute acid, as hydrochloric, be added to a hot solution of urate of ammonia, the latter is decomposed, and the uric acid set free; which, being insoluble even in hot water, is precipitated in the form of minute crystals (Fig. 3, page 6).

376. With nitric acid and ammonia, urate of ammonia produces the same results as uric acid (371).

377. Urate of ammonia dissolves readily in a warm solution of potash, giving off at the same time ammoniacal fumes; by which it may be distinguished from uric acid and urate of soda. The addition of a dilute acid to the hot solution, causes a crystalline precipitate of uric acid (373).

SECTION IV.

Phosphate of Lime ($8CaO,3PO_5$).

378. Calculi of phosphate of lime are most commonly smooth and even polished on the surface. The concentric laminæ are generally arranged with considerable regularity (Fig. 54); and when the calculus is broken, these separate from each other with great facility, forming detached crusts. The colour is usually pale fawn or stone colour.

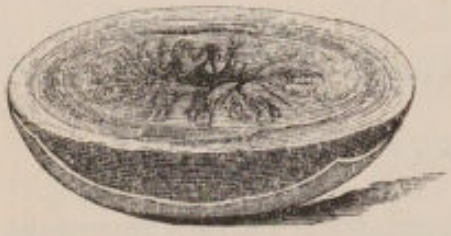

Fig. 54.
Phosphate-of-lime calculus.

379. Before the blowpipe, it chars, owing to the presence of a little animal matter; and gradually becomes white, as the carbonaceous matter burns away. It is almost infusible, requiring for its fusion so intense and prolonged a heat, that few can succeed in fusing it.

380. The residue, after ignition, is neutral to test paper.

381. It is soluble, without effervescence, in dilute nitric or hydrochloric acid (49).

382. Divide the solution in nitric acid, formed in the last experiment, into three parts, and neutralize the first

portion with ammonia; the phosphate of lime is again thrown down unchanged, in the form of a gelatinous amorphous precipitate (49).

383. To the second portion of the acid solution, add a drop or two of nitrate of silver, and cautiously *neutralize* the mixture with dilute ammonia; a pale yellow precipitate of phosphate of silver ($3AgO,PO_5$) will be thrown down, which is soluble both in ammonia and nitric acid.

384. To the third portion of the nitric acid solution, add dilute ammonia until it is nearly neutral, taking care that it is not added in sufficient quantity to cause the precipitation of the phosphate of lime (382). Test the solution with oxalate of ammonia, which throws down a copious white precipitate of oxalate of lime (47 *b*).

385. If a little of the pounded phosphate of lime be mixed with about twice its bulk of the double phosphate of ammonia and magnesia, or triple phosphate (MgO, NH_4O,HO,PO_5), and heated before the blowpipe on platinum wire, it readily fuses. The *fusible calculus* is composed of a similar mixture of the two salts (391).

SECTION V.

Phosphate of Ammonia and Magnesia, or Triple Phosphate (MgO,NH_4O,HO,PO_5).

386. Calculi composed entirely of triple phosphate are of somewhat rare occurrence; but mixed, or alternating with other matters, and indeed constituting the great bulk of the concretion, this substance is very common. Such calculi are sometimes found to have been deposited in concentric layers, and sometimes consist of an aggregated mass of prismatic crystals. They are usually nearly colourless, or slightly tinged with drab or stone colour. The surface is most commonly rough and uneven, and often covered with small, shining crystals.

387. The triple phosphate, when heated before the blowpipe, chars, and gives off the smell of ammonia; swells up, gradually becomes grey as the carbonaceous matter is consumed, and ultimately fuses.

388. It is almost insoluble in water, but if boiled, a small quantity will be found to dissolve.

389. It dissolves readily in dilute hydrochloric, and most other acids, and is again thrown down, in the form of a crystalline precipitate, when the solution is neutralized with ammonia. If the precipitate thus obtained be examined under the microscope, it will be found to consist of well defined crystals, which, if the solution has been supersaturated with the ammonia, are stellate (Fig. 10, page 15); but if merely neutralized, they are prismatic (Fig. 8, page 15), (44).

390. When heated with a solution of potash, it is decomposed, the potash combining with the phosphoric acid, and setting free the ammonia and the magnesia. The former volatilizes, and may be detected by the smell, while the magnesia is precipitated (49).

$$MgO,NH_4O,HO,PO_5+2KO=2KO,HO,PO_5+NH_3+MgO,HO.$$

SECTION VI.

Fusible calculus, which is a mixture of Phosphate of Lime ($8CaO,3PO_5$) *and the Double Phosphate of Ammonia and Magnesia* (MgO,NH_4O,HO,PO_5).

391. The fusible matter of which this form of calculus is composed, is, next to uric acid, the most common of the ingredients of calculi. It sometimes constitutes the entire mass of the calculus; is also frequently found alternating with other ingredients; and very commonly forms the outer crust of calculi composed of uric acid and other matters. Fusible calculi are generally oval or irregular in form (Fig. 55); white, soft, and friable, resembling chalk; though occasionally they are compact and hard.

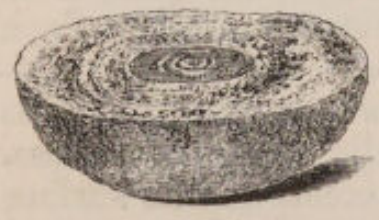

Fig. 55. Fusible calculus.

392. This calculus is chiefly characterized by the readiness with which it fuses before the blowpipe, without being consumed; in which respect it differs from all other kinds of calculus. During the ignition, the ammonia and water are expelled, leaving a mixture of the phosphates of lime and magnesia.

393. If a portion of the calculus be dissolved in dilute hydrochloric acid, nearly neutralized with ammonia, and treated with oxalate of ammonia, the lime is separated as oxalate (47, *b*), while most of the magnesia remains in solution.

394. If the ammonia be added to the acid solution of the calculus (393) until it causes a precipitate, the mixed phosphates of lime, and of ammonia and magnesia are thrown down. When examined under the microscope, the first appears as an amorphous powder, the latter distinctly crystalline (43).

SECTION VII.

Oxalate-of-Lime Calculus (CaO,C_2O_3).

395. Calculi are not unfrequently met with, composed almost entirely of oxalate of lime; but more commonly the nucleus will be found to consist of uric acid or urate of lime. Oxalate-of-lime calculi are usually very dark in colour, either brown or dark olive, or a kind of dirty purple. Their surface is much more irregular and rugged than other descriptions of calculi; and when sawn asunder, they exhibit an irregular and angular structure, as shown in figure 56. From their resemblance to the fruit of the mulberry, this variety is commonly known as the *mulberry calculus*.

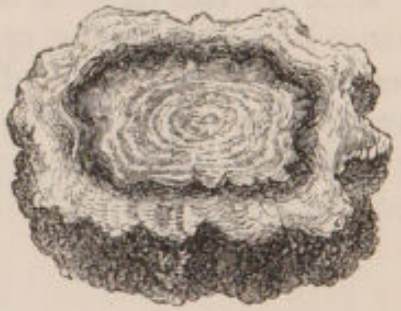

Fig. 56. Oxalate-of-lime calculus.

396. There is also another form in which oxalate-of-lime calculi are occasionally met with, commonly called *hempseed* calculi. These are small, round or oval, and very smooth and polished on the exterior; they generally contain also a little urate of ammonia. The general form and appearance of these oxalate-of-lime calculi, are usually so peculiar and characteristic, that they may be, in most cases, easily recognised by simple inspection.

397. Pounded oxalate of lime dissolves without effervescence in dilute nitric and hydrochloric acids, and is again thrown down unchanged, in the form of a white precipitate, when the acid solution is neutralized with ammonia. Occasionally a little carbonate of lime is found mixed with the

oxalate, in which case, slight effervescence will, of course, take place on the addition of the acid.

398. Oxalate of lime is insoluble in acetic and oxalic acids.

399. When heated before the blowpipe it blackens, and gives off a disagreeable smell, resembling that of burnt feathers. If the heat be continued a short time, the residue becomes white, and then consists of carbonate of lime, into which the oxalate is converted; carbonic acid being also, with other gaseous matters, at the same time given off.

$$CaO,C_2O_3+O=CaO,CO_2+CO_2.$$

400. Treat the residue formed in the last experiment with dilute hydrochloric acid; it readily dissolves, with effervescence, showing that it has been changed into the carbonate.

401. The solution of chloride of calcium (*CaCl*) thus formed may be neutralized with ammonia, and tested for lime with oxalate of ammonia, which will throw down the oxalate of lime (CaO,C_2O_3+2Aq), in the form of a white precipitate (171).

402. If the oxalate of lime be kept intensely heated for some little time, the carbonate which is at first formed is reduced to the state of caustic lime (CaO); which may be proved by placing the residue, when cold, on a piece of moistened turmeric paper, the yellow colour of which will be turned to brown.

SECTION VIII.

Urate (or Lithate) of Lime ($CaO,C_{10}N_4H_4O_6$).

403. This substance, though never found composing entire calculi, is not unfrequently present in small quantities in concretions which consist chiefly of uric acid, oxalate of lime, or other matters.

404. Urate of lime is nearly insoluble in cold water, but dissolves in hot, though somewhat less readily than urate of ammonia (375). The hot aqueous solution deposits it again on cooling, generally in the form of minute needle-shaped crystals.

405. Like the other urates, it is decomposed by hydrochloric acid. If the acid be added to a hot aqueous solution of the salt, a crystalline precipitate of uric acid is thrown

TABULAR VIEW OF THE DISTINCTIVE CHARACTERS OF CALCULI.

(SLIGHTLY ALTERED FROM SCHARLING.)

SPECIES.	FORM.	COLOUR.	TEXTURE.	SURFACE.			SIZE.	SPECIFIC GRAVITY.	CHEMICAL AND BLOWPIPE CHARACTERISTICS.	FORM OF CRYSTALS.
				EXTERNAL.	INTERNAL.					
					CUT.	FRACTURED.				
Uric acid. $C_{10}N_4H_4O_6$	Ovoid, or spheroid when single. Forming facettes and angles when numerous.	Yellowish fawn; reddish brown; colour of mahogany; never grey or white.	Dense, compact, and frangible.	Smooth, or finely tuberculated.	Smooth and polished, formed of concentric layers and striæ.	Crystalline when pure; earthy when mixed with other ingredients.	From that of a pea to that of a duck's egg.	1.276 to 1.786	Combustible; exhales odour of burnt bone and hydrocyanic acid before B.P. Soluble in nitric acid, yielding pink stain on evaporation, changed to purple by ammonia. Soluble in solution of caustic potash.	Rhomboid, lozenge-shaped plates, &c. Fig. 30.
Urate of ammonia. $NH_4O,C_{10}N_4H_4O_6$	Compressed spheroid or amygdaloid.	Clay coloured; slate coloured; "couleur de caffé au lait."	Frangible.	Finely tuberculated.	Smooth and even; thin concentric layers.	Finely earthy; granular like compact limestone.	From that of a pea to that of a marble.	1.225 to 1.720	Combustible, decrepitating and yielding strong odour of ammon. before B.P. Soluble in nitric acid, yielding uric acid reaction. Soluble in boiling water, and carbonated alkalies. Exhales vapour of ammonia when heated with potash.	Amorphous, or minute globules. Fig. 11.
Phosphate of lime. $8CaO,3PO_5$	Spheroidal.	Pale brown, or greyish white.	Compact.	Smooth, polished and porcelaneous.	Laminated; the layers easily separable; striated perpendicularly to the surface.	Semi-crystalline; conchoidal.	Moderate.		Incombustible; infusible except under intense heat before B.P. The B.P. residue soluble in hydrochloric and nitric acids; reprecipitated by ammonia. The B.P. residue insoluble in acetic or very dilute sulphuric acids. The B.P. residue insoluble in water, not alkaline.	Amorphous.
Triple phosphate. MgO,NH_4O,HO,PO_5	Compressed spheroid; compressed ovoid; pyriform; reniform.	Nearly white.	Friable. Powder not gritty.	Uneven; studded with sharp shining crystals.	Earthy, pulverulent, crystalline; not striated.	Clusters of crystals imbedded in friable matter, or lining the walls of cavities and fissures.	Usually large.		Incombustible, fuses with difficulty, evolves ammonia before B.P. Soluble in dilute hydrochloric, nitric, and acetic acids. Precipitable without decomposition by ammonia from acid solution. The B.P. residue insoluble in water and not alkaline. The B.P. residue soluble without effervescence in acids; yields crystalline precipitate when ammonia is added to the acid solution in excess.	Stellate or prismatic. Fig. 7.
Fusible.	Very irregular; round; pyriform; reniform; lobulated.	Quite white.	Very white, leaving a chalk-like streak.	Spongy, rough, not tuberculated nor spinous.	Indistinct layers, united by crystals of triple phosphate.	Earthy, with clusters of triple phosphate sprinkled throughout.	Generally large, frequently very large.	1.140 to 1.470	Incombustible, speedily and readily fusible into a white bead before B.P. The B.P. residue soluble in acids without effervescence; reprecipitated by ammonia. The B.P. residue insoluble in water, and not alkaline.	
Oxalate of lime. CaO,C_2O_3	Spheroidal, octohedral, cubical.	Deep brown; olive, or blackish green; dull purple, sometimes whitened with the phosphates.	Very compact and dense.	Spinous and rugged.	Excentric laminæ, arranged like fortification agate, smooth and polished.	Uneven, splintery.	Moderate.	1.428 to 1.976	Incombustible and infusible; expands into a white efflorescence before B.P. Soluble slowly in nitric and hydrochloric acids, without effervescence. The B.P. residue soluble with effervescence in acids. The B.P. residue insoluble in water, yielding, after strong ignition, an alkaline reaction.	Acute octohedrons. Fig. 23.
Cystic oxide. $C_8NH_8O_4S_2$	Oval oblong.	Tawny yellow, becoming green in time.	Consistence of wax, resembles stearine in appearance.	Covered with smooth tubercles, or sharp crystalline projections.	Confusedly radiated, but not laminated.	Exhibits a peculiarly refractive lustre. May be scraped into a white powder.	Moderate.		Combustible; yields an odour like that of sulphuret of carbon before B.P. Soluble in liquid ammonia, fixed alkalies, and many acids. The ammoniacal solution yields on evaporation hexagonal plates. Insoluble in carbonate of ammonia, acetic, citric, and tartaric acids. Yields a brown stain when dissolved in excess of nitric acid and evaporated.	Hexagonal or roundish tables, opaque in the centre. Fig. 26.
Carbonate of lime. CaO,CO_2	Spherical.	White.	Friable.	Smooth.			Very small.		Incombustible and infusible. Soluble in acids with effervescence. The B.P. residue, after strong ignition, soluble in acids *without* effervescence.	
Xanthic, or uric oxide. $C_5N_2H_2O_2$	Ovoid, flattened at the sides.	Brownish red, resembling that of cinnamon.	Compact and hard.	Smooth. Resinous lustre when rubbed.	Laminated, neither fibrous nor crystalline.	Partly brown and lustrous, partly white and earthy.	Moderate.		Combustible, splitting into fragments, exh. peculiar fœtid odour before B.P. Soluble, without effervescence in nitric acid; yielding lemon yellow stain on evaporation. Soluble in strong sulphuric acid, not precipitable by water. Insoluble in solution of carbonate of potash.	Amorphous.

To face p. 111.

down (377, 373), and chloride of calcium remains in solution.

$$CaO,C_{10}N_4H_4O_6 + HCl = CaCl + HO + C_{10}N_4H_4O_6.$$

406. When tested with nitric acid and ammonia, in the manner described in paragraph 371, urate of lime behaves like uric acid and the other urates, yielding the rich purple colour of murexide.

407. As this is the only salt of lime found in calculi which is soluble in hot water, it may be supposed to be present when, after boiling a little of the pounded calculus in water, the *hot* aqueous solution gives a white precipitate of oxalate of lime when tested with oxalate of ammonia (171).

SECTION IX.

Cystine ($C_6NH_6O_4S_2$).

408. Calculi of cystine are of rather rare occurrence. They are usually more or less crystalline in structure, not deposited in laminæ, soft, and of a pale brownish yellow or greenish tint. Small calculi composed almost exclusively of this substance are frequently found in the dog.

409. The chemical characters of cystine, and the methods of distinguishing it by tests, will be found described in the chapters on urine (172, 269, &c.)

410. The annexed table shows the principal peculiarities of the several varieties of urinary calculi.

CHAPTER II.

QUALITATIVE EXAMINATION OF URINARY CALCULI, THE COMPOSITION OF WHICH IS UNKNOWN.

411. When a calculus has to be examined with a view to ascertaining the nature of its ingredients, a very few simple experiments, conducted on some such plan as the following, will generally furnish the required information. The calculus should first be sawn through, and the loose dust

gently brushed away. If the several laminæ of which the mass is composed appear to be homogeneous, and to consist of the same kind of matter, a small fragment may be taken from any part of it for examination (412); but if, as is more frequently the case, there appear to be two or more different kinds of matter contained in the several layers (367), fragments of each of them should be carefully detached from the mass, and examined separately in the following manner.

412. Place a small fragment on platinum foil, and heat it to redness before the blowpipe, until the blackness of the charred animal matter disappears. Observe whether,—

(*a*) IT BURNS AWAY, LEAVING ONLY A MINUTE TRACE OF ASH (413);

(*b*) IT PROVES INCOMBUSTIBLE, WITHOUT MATERIALLY LESSENING IN BULK (414);

(*c*) IT IS PARTIALLY CONSUMED, leaving, however, a considerable residue of incombustible matter (415).

413. IF IT BURNS AWAY, leaving only a minute trace of incombustible ash, it is probably either uric acid, urate of ammonia, or cystine; or possibly a mixture of two or more of them. See 416—419.

414. IF IT IS INCOMBUSTIBLE, not materially lessening in bulk during the ignition, it is probably either phosphate of lime, triple phosphate, fusible matter (391), oxalate of lime (converted into carbonate by the heat), urate of lime (also converted into carbonate); or perhaps two or more of those substances mixed together. See 420—425.

415. IF THE FRAGMENT IS PARTIALLY CONSUMED, it will probably be found to consist of a mixture of one or more of the combustible substances mentioned in paragraph 413, with some of those enumerated in paragraph 414. See 426—428.

Examination of Combustible Calculi (413).

416. If the calculus (in powder) is found to be INSOLUBLE IN WARM WATER; SOLUBLE IN SOLUTION OF POTASH, without the evolution of ammonia; and to form, when tested with nitric acid and ammonia, a PURPLE RESIDUE; it is probably URIC ACID (370, 372, 371). (Confirm 373.)

417. If it is found to be SOLUBLE IN HOT WATER; SOLUBLE IN SOLUTION OF POTASH, with the evolution of ammoniacal fumes; and to yield, with nitric acid and

ammonia, a PURPLE RESIDUE; it is probably URATE OF AMMONIA (375, 377, 376). (Confirm 373.)

418. If it is found to be INSOLUBLE IN WARM WATER; readily SOLUBLE IN AMMONIA; the ammoniacal solution yielding, on slow evaporation, HEXAGONAL CRYSTALLINE PLATES, it is probably CYSTINE (174, 173). (Confirm 174, 271, 273.)

419. If it is suspected that more than one of the above substances are present, a little of the powder may be boiled with water, and, if any portion remains undissolved, the mixture filtered *while hot*.

(*a*) If the clear filtered liquid DEPOSITS, ON COOLING, AN AMORPHOUS PRECIPITATE, URATE OF AMMONIA is probably present (375). (Confirm 417.)

(*b*) If the insoluble portion gives a PURPLE COLOUR when tested with nitric acid and ammonia, URIC ACID is probably present (371). (Confirm 416.)

(*c*) If the insoluble portion is wholly or partially SOLUBLE IN AMMONIA; the ammoniacal solution yielding, on evaporation, HEXAGONAL PLATES, CYSTINE is probably present (173). (Confirm 418.)

Examination of Incombustible Calculi (414).

420. If the matter of the calculus is INFUSIBLE BEFORE THE BLOWPIPE; SOLUBLE IN DILUTE HYDROCHLORIC ACID; the acid solution of the substance after ignition, yielding, when neutralized with ammonia, an AMORPHOUS PRECIPITATE, it is probably PHOSPHATE OF LIME (379, 381, 382). (Confirm 383, 384.)

421. If it is TOLERABLY FUSIBLE before the blowpipe; SOLUBLE IN DILUTE HYDROCHLORIC ACID; the acid solution giving, when neutralized with ammonia, a CRYSTALLINE PRECIPITATE, it is probably TRIPLE PHOSPHATE (387, 389). (Confirm 390.)

422. If it is READILY FUSIBLE before the blowpipe; SOLUBLE IN DILUTE HYDROCHLORIC ACID; the acid solution yielding, when supersaturated WITH AMMONIA, A PRECIPITATE, which when examined under the microscope, is found to contain both AMORPHOUS PARTICLES and also CRYSTALLINE STELLÆ, it is probably composed of the MIXED, OR FUSIBLE PHOSPHATES (392, 394). (Confirm 393.)

423. If the substance, previous to ignition, is SOLUBLE WITHOUT EFFERVESCENCE in dilute hydrochloric acid; the acid solution yielding a WHITE PRECIPITATE WHEN NEUTRALIZED WITH AMMONIA; and after gentle ignition, is SOLUBLE WITH EFFERVESCENCE in the dilute acid; the acid solution, moderately diluted, now yielding NO PRECIPITATE when neutralized with ammonia, it is probably OXALATE OF LIME (397, 400, 401). (Confirm 398, 402.)

424. If the hot aqueous solution, formed by boiling a little of the pounded calculus with water, gives a WHITE PRECIPITATE WITH OXALATE OF AMMONIA, the presence of URATE OF LIME is indicated (407). (Confirm 404, 405, 406.)

425. If it is suspected that more than one of the above substances are present in the portion of calculus under examination, it may be gently ignited, and then treated with dilute hydrochloric acid.

(*a*) IF EFFERVESCENCE ENSUES (the calculus, previous to ignition, not causing effervescence with the acid), oxalate (or possibly urate (*c*),) of lime is probably present (397, 400). (Confirm 423.)

(*b*) Supersaturate the acid solution with ammonia; and if any PRECIPITATE IS PRODUCED, examine it under the microscope for PHOSPHATE OF LIME and TRIPLE PHOSPHATE (382, 389). (Confirm 420, 421.)

(*c*) Boil a little of the pounded calculus previous to ignition, with water; and test the *hot* aqueous solution thus obtained, with oxalate of ammonia. If a WHITE PRECIPITATE is produced, URATE OF LIME is probably present (407). (Confirm 424.)

Examination of partially Combustible Calculi (415).

426. When the calculus, or any portion of it, is found to be partially consumed when ignited, it is probably a mixture of one or more of the combustible matters enumerated in paragraph 413, associated with one or more of the incombustible ingredients mentioned in paragraph 414.

427. A portion of the calculus, previous to ignition, may first be examined for the organic or combustible ingredients, in the manner described in paragraph 419, *a*, *b*, & *c*.

428. Another portion of the calculus may then be gently ignited on platinum foil, and the residue examined for the inorganic matters, according to the directions given in paragraph 425, *a*, *b*, & *c*.

CHAPTER III.

BILIARY CALCULI OR GALL-STONES.

429. Biliary calculi are usually of a pale yellow or brownish colour; soft, soapy to the touch, and easily crushed into small fragments by pressure; and the texture of the mass is in most cases decidedly crystalline. The size most commonly met with, is about that of a pea; but they are frequently found much smaller, and occasionally as large as a pigeon's egg. The form is generally irregular and somewhat angular, as shown in figure 57.

Fig. 57. Biliary calculi.

430. They usually contain from fifty to eighty per cent. of cholesterin ($C_{36}H_{32}O$); the rest of the concretion being made up of biliary resin and colouring matter, mucus, and traces of other animal matters, with a small quantity of inorganic salts. The composition of three specimens analyzed by Brande was as follows :—

	I.	II.	III.
Cholesterin	81.25	69.76	81.77
Biliary resin	3.12	5.66	3.83
Bile pigment	9.38	11.38	7.57
Albumen and salts extractable by water	——	——	3.83
Biliary mucus	6.25	13.20	——

431. Heat a small fragment of gall-stone on platinum foil; it will burn with a bright but smoky flame, leaving a small fixed residue, consisting of inorganic salts.

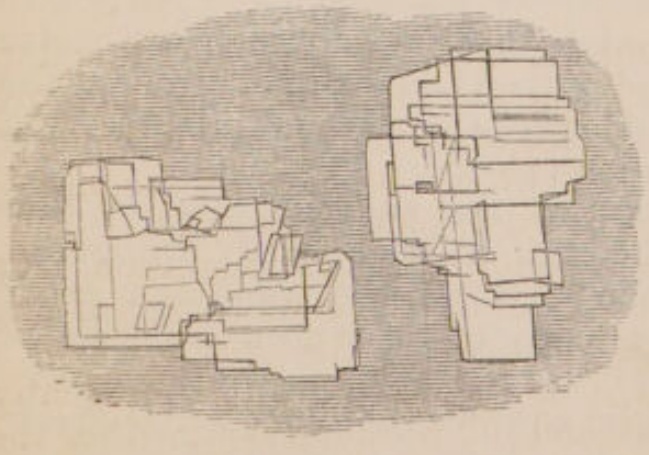

Fig. 58. Cholesterin.

432. When coarsely pounded, it dissolves readily in boiling alcohol; and on cooling, the cholesterin crystallizes out in the form of fine scaly crystals (Fig. 58), while the biliary resinous and colouring matters remain in solution, giving the liquid a yellowish tinge.

433. It is insoluble in dilute nitric and hydrochloric acids.

434. It is insoluble also in a solution of potash; thus differing from other fatty and oily substances, which cholesterin resembles in many respects.

CHAPTER IV.

GOUTY CONCRETIONS.

435. These earthy concretions, which form in the joints of gouty persons, are usually white, or nearly so, soft and friable, closely resembling chalk in appearance, and hence commonly known as *chalk stones*. They seem to vary a good deal in composition; but in the great majority of those which have been analyzed, urate of soda ($NaO,C_{10}N_4H_4O_6$) appears to form the principal and most characteristic ingredient. They contain also a considerable quantity of chloride of sodium and dried cellular tissue; with occasionally urate of lime ($CaO,C_{10}N_4H_4O_6$), phosphate of lime ($8CaO,3PO_5$), and chloride of potassium. The presence of a large quantity of uric acid may be shown by the formation of the purple-coloured murexide, when a little of the concretion, in powder, is treated with nitric acid and ammonia, in the manner described in paragraph 371.

Qualitative examination of Gouty Concretions.

436. Reduce the concretion intended for analysis, to tolerably fine powder, and digest it in cold water to dissolve out the chlorides of sodium and potassium. Filter the solution from the insoluble portion, which must be reserved for subsequent examination (440).

437. Test a few drops of the aqueous solution thus formed, with nitrate of silver. A white curdy precipitate, which is readily soluble in ammonia, but insoluble in nitric acid, will show the presence of CHLORINE (chloride of sodium) (41, *a*).

438. Mix the rest of the aqueous solution with bichloride of platinum; evaporate the mixture to dryness, or nearly

so, on a water bath; and observe the yellow needle-shaped crystals of the double chloride of sodium and platinum ($NaCl,PtCl_2$) showing the presence of SODA (chloride of sodium) (41, *f*).

439. Add a little alcohol to the evaporated residue, and observe whether any small sandy-looking crystals remain undissolved, indicating the presence of POTASH (41, *e*).

440. The portion which proved insoluble in cold water (436), may now be treated with hot water, and gently boiled with successive small quantities of the liquid as long as anything appears to dissolve. The urate of soda is thus slowly dissolved, together with any urate of lime that may be present (97, 404). The matter which proves insoluble in the hot water is to be retained for subsequent examination (444).

441. Hydrochloric acid is now added in slight excess to the hot aqueous solution, and the mixture set aside until it cools, in order to allow the uric acid, which will have been displaced from the soda and lime by the hydrochloric acid (405), to separate completely from the solution. The uric acid is thus precipitated; leaving in solution chloride of sodium, and also, in case any urate of lime was present in the concretion, a little chloride of calcium.

442. The mixture thus obtained is filtered. The URIC ACID may be examined with the microscope and with other tests (373, 371); and a little of the aqueous solution may be neutralized with ammonia, and tested for LIME with oxalate of ammonia (171).

443. The rest of the aqueous solution may be evaporated at a gentle heat with bichloride of platinum; when the yellow needles of the double chloride of sodium and platinum (41, *f*) will prove the presence of a large quantity of SODA derived from the urate (435).

444. The remaining portion of the concretion, which resisted the action of the hot water (440) may now be examined. It will probably be found to consist chiefly of dried cellular matter, with perhaps a little phosphate of lime (435). The animal matter may be burnt away, by keeping it at a red heat until the blackness disappears; after which the incombustible residue may be examined in the manner described in paragraph 425, and will probably be found to consist of phosphate of lime.

445. The following is an analysis by T. J. Herapath, of

some concretions taken from the joints of the fingers of a man suffering from gout:—

Fat	1.123
Chloride of sodium, Phosphate of soda, Extractive matter, Albumen	traces
Urate of soda, with some urate of potash	43.973
Urate of lime	14.769
Phosphate of lime	34.141
Perphosphate of iron	traces
Water and loss	5.994
	100.000

PART III.

BLOOD.

CHAPTER I.

HEALTHY BLOOD.

SECTION I.

General Characters of Blood.

446. The general appearance of blood, as it flows from the vessels through which it circulates in the living body, is familiar to every one, as an opaque, slightly viscous fluid, of a more or less brilliant red colour; that from the arteries being brighter and more scarlet than that from the veins. It has, while warm, a faint though characteristic odour, differing in the blood of different animals, and a saline and disagreeable taste. The specific gravity of healthy blood appears to vary from 1050 to 1058, the average being about 1055. It is always alkaline to test paper.

447. While circulating in the vessels, blood consists of a nearly colourless and transparent liquid, in which float myriads of minute vesicular bodies or corpuscles, of which by far the greater number are of a bright red colour; and these being so small as to be individually quite invisible without the aid of a tolerably good microscope, give the blood, when seen with the naked eye, the appearance of being a homogeneous red fluid (451). A few of the corpuscles are colourless, and differ also in other respects from the red ones (464). The fluid portion of the blood, in which the corpuscles float, is usually called the *liquor sanguinis*.

448. The most remarkable peculiarity presented by the blood, is the spontaneous coagulation which it begins to undergo almost immediately after being drawn, gradually separating into a more or less firm and solid red coagulum or *clot*, consisting of coagulated fibrin mixed with the cor-

puscles, and a pale yellowish transparent watery liquid, called the *serum*, holding in solution all the other solid matters of the blood. The nature and cause of this phenomenon will be more fully explained further on (473). The specific gravity of the serum is lower than that of the entire blood, being about 1029.

449. The chemical composition of the blood is highly complex; and though the nature of the principal ingredients is now tolerably well understood, our knowledge of the more obscure parts of its history is still very imperfect. The following substances appear to enter into its composition (Simon), and probably further researches will reveal the presence of other compounds, and, perhaps, also prove the non-existence of some of those now included in the list.

	Water,
Protein compounds	Albumen,
	Fibrin,
	Globulin,
Colouring matters	Hæmatin,
	Hæmaphæin,
Extractive matters	Alcohol extractive (containing traces of urea),
	Water extractive,
Fatty matters	Cholesterin,
	Serolin,
	Margaric acid,
	Oleic acid,
	Red and white solid fats, containing phosphorus.
Saline matters	Oxide of iron,
	Albuminate of soda,
	Phosphates of lime, magnesia, and soda,
	Sulphates of potash and soda,
	Carbonates of lime, magnesia, and soda,
	Chlorides of sodium and potassium,
	Lactate of soda,
	Oleate and margarate of soda,
Gases	Oxygen,
	Nitrogen,
	Carbonic acid,
	Sulphur,
	Phosphorus.

450. It will, however, be more convenient for our present purpose, to consider the constituents of the blood as arranged in the following manner, the more important substances only being placed separately, and the others being, for the sake of simplicity, grouped together.

Water,
Red and white corpuscles,
Albumen,
Fibrin,
Alcohol extractive,
Water extractive,
Oily fats,
Crystalline or solid fats,
Fixed saline matters.

A short description of each of these substances and groups will assist in rendering the subsequent analytical operations, both qualitative and quantitative, more simple and intelligible to the student.

SECTION II.

Blood Corpuscles.

451. If freshly drawn blood, previous to coagulation, be examined under the microscope, it will be found to consist of a transparent and nearly colourless fluid, in which float innumerable minute, circular, disk-shaped bodies or corpuscles, of which by far the greater number appear of a pale yellowish colour, though they are in reality red; the paleness of the colour being caused by the red rays from each of the corpuscles being spread over so large a surface. It is to these corpuscles that the red colour and opacity of the blood are due, the *liquor sanguinis*, or fluid portion of the blood, in which they float, being nearly colourless and perfectly transparent.

452. These little bodies, which, when the blood is first drawn, float freely in the *liquor sanguinis*, occasionally adhere together, forming little aggregations resembling strings of beads or rolls of coin (Fig. 59); this arrangement, however, is not always permanent, and the corpuscles gradually become again disunited and scattered. The ten-

dency to aggregate together is usually greater during the inflammatory state, frequently causing the red corpuscles to collect in irregularly-shaped masses, which sink more rapidly than when they are detached from each other. This is one of the causes which tend to produce what is known as the *buffy coat*, which was formerly supposed to be always indicative of inflammation, but which has since been found to be formed almost whenever the fibrin, from whatever cause, coagulates more slowly, or the corpuscles subside more rapidly, than in healthy blood (454, 473).

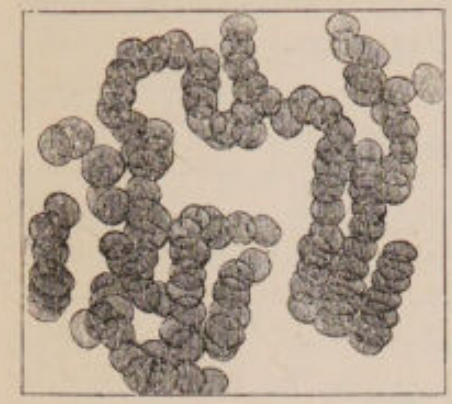

Fig. 59. Blood corpuscles, magnified 400 diameters.

453. The red corpuscles of human blood vary from $\frac{2}{10000}$ths to $\frac{5}{10000}$ths of an inch in diameter, the average size being about $\frac{3}{10000}$ths of an inch. They are nearly circular, flattened disks, each being slightly depressed and concave in the centre; their thickness is usually about one-fourth or one-fifth of their diameter (Fig. 60).

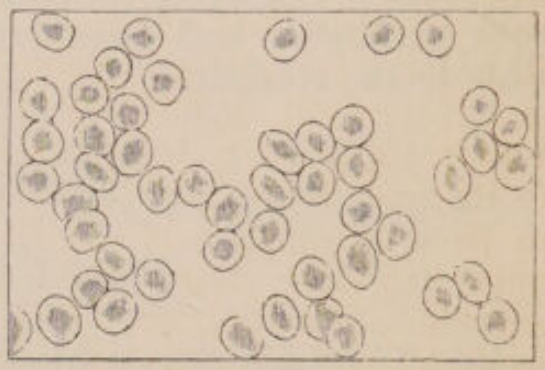

Fig. 60. Blood corpuscles, magnified 400 diameters.

454. When, owing to the solidification of the fibrin, the blood coagulates (473), the corpuscles gradually become entangled in the network of the solidifying clot, which is, in consequence, of a bright red colour; while the serum, or defibrinated *liquor sanguinis*, is left nearly colourless as the clot subsides. In consequence of the corpuscles being slightly heavier than the liquid in which they float, they begin very slowly to subside almost immediately after the blood is drawn; so that the lower portion of the clot usually contains a larger proportion of them, and has consequently a deeper colour, than the upper. This is the case to a remarkable extent in certain morbid conditions of the blood, which will be noticed further on (589).

455. The red corpuscles appear to consist of delicate

membranous vesicles, filled with the red fluid to which they owe their peculiar colour, which fluid is supposed to consist of a colouring matter containing a considerable quantity of iron, to which the name of hæmatin has been given, associated with a protein compound, in many respects analogous to albumen, and called globulin. The enclosing membrane, which is highly elastic, appears to be composed either of coagulated fibrin or albumen, or of some other modification of protein closely allied to them.

456. When placed in solutions of different densities, the phenomena of endosmosis and exosmosis presented by the corpuscles, are very curious and interesting, and may be seen with great facility with the help of a tolerable microscope. As long as the fluid in which they float is of the same density as that which they contain, such, for instance, as the liquor sanguinis, the corpuscles experience little or no change of form. But if the external liquid is less dense than that contained in the corpuscles, the latter will become more or less distended and globular, owing to the lighter fluid, in obedience to the well-known laws of endosmosis, passing through the membranous vesicles into the interior more rapidly than the heavier fluid within can pass outwards. If, on the other hand, the external liquid be more dense than that contained within the corpuscles, the contrary effect will be produced, and the corpuscles will immediately begin to collapse, and assume a wrinkled appearance (Fig. 60). This change of form not unfrequently takes place spontaneously, while a drop of blood, placed between two surfaces of glass, is being examined under the microscope; especially near the edges, where, owing to evaporation, the liquid with which the corpuscles are in contact, gradually becomes more concentrated, and consequently more dense.

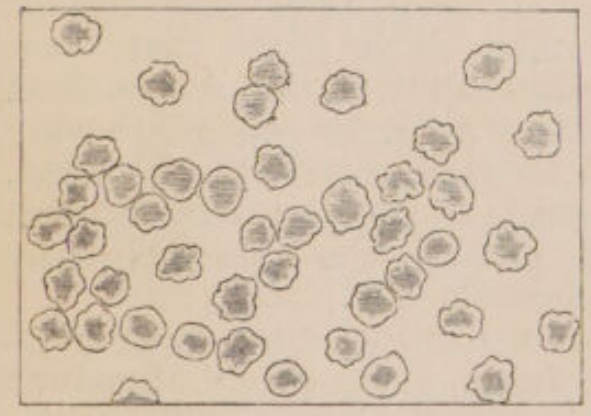

Fig. 60. Blood corpuscles collapsed, magnified 400 diameters.

457. The liquor sanguinis, or fluid portion of the blood, as it exists in the living body, and before it undergoes coagulation, appears to possess the same density as the

red fluid contained in the vesicles; so that as long as it continues so, no change takes place in the form of the corpuscles. When, however, the fibrin, which was before dissolved in the liquor sanguinis, has coagulated, the resulting serum becomes less dense, in consequence of its holding in solution a smaller amount of solid matter (448). The effect of this upon the blood corpuscles, is to cause them, when in contact with the serum of coagulated blood, to enlarge in size, in consequence of the increased rapidity with which the less dense serum enters through the membranous integument.

458. If the red corpuscles be brought in contact with water, the change is extremely rapid; they instantly swell to a much larger size, the vesicles becoming less and less distinct, until at length, unless the quantity of water is very small, they almost entirely disappear.

459. When, owing to the action of water, or some other liquid of comparatively low specific gravity, the corpuscles have become distended, they may, if the distention has not been allowed to go too far, be again brought back almost to their original size; and even be made to assume a wrinkled appearance, by bringing them in contact with a tolerably strong solution of sugar, or of certain salts, as chloride of sodium, or muriate of ammonia.

460. The corpuscles readily dissolve in a solution of potash, ammonia, acetic acid, and some other fluids.

461. Although we are unable to separate the corpuscles from the blood by filtration, since they pass readily through the pores of the filter, it is found that when mixed with certain strong saline solutions, they are retained by it. A solution of sulphate of soda, for example, having a specific gravity of about 1.13 when mixed with the blood, effectually prevents the passage of the corpuscles through the filter. This remarkable property has been applied by Figuier to the purposes of analysis (582).

462. When blood is allowed to dry at common temperatures, and is subsequently moistened, even after the lapse of a considerable time, with some liquid having a specific gravity similar to that of the serum (448), the corpuscles are found to have retained their characteristic form and appearance, and may be readily distinguished under the microscope. This circumstance has been ingeniously applied for the purpose of solving a question, which in some medico-legal

inquiries is one of grave importance—viz., whether the stains found on clothing, or elsewhere, are, or are not, stains of blood. The methods hitherto devised of identifying minute traces of blood by means of chemical tests are very imperfect and unsatisfactory; so that the assistance afforded by the microscope here becomes of the highest value.

463. For this purpose, the stain is to be moistened and gently rubbed with a little fresh white of egg, or some other fluid having a specific gravity of about 1030 to 1050. It is then scraped off, and a little of the mixture examined under the microscope with a tolerably high power; when, if the stain consisted of blood, the characteristic corpuscles will be distinctly visible.

464. *White corpuscles of the blood.*—In addition to the red corpuscles, there are always present in the blood a few colourless particles, somewhat larger than the coloured ones, and otherwise differing from them in general appearance and structure (Fig. 62). They are of irregular forms, sometimes spherical, slightly granular on the surface, and appear to be identical, or nearly so, with the peculiar corpuscles always present in the lymph and the chyle. When treated with acetic acid, the granular exterior becomes transparent, as in the corpuscles of pus, and one or more internal nuclei are rendered visible.

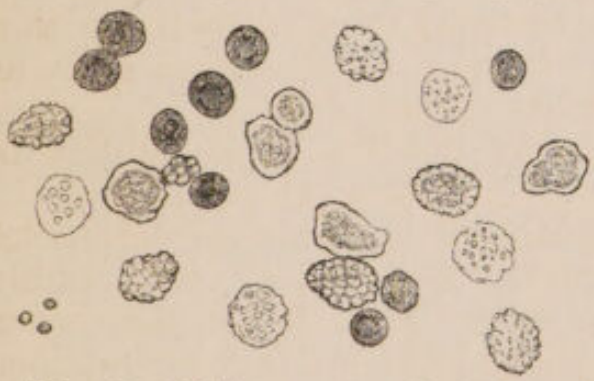

Fig. 62. White corpuscles of the blood, magnified 400 diameters.

465. The proportion of corpuscles present in healthy blood is usually about 130 parts in 1000 (573).

SECTION III.

Albumen.

466. This is one of the most important of the constituents of the blood, and with the exception of the red corpuscles, is present in larger quantity than any of the other solid

matters contained in it. It is held in solution in the serum, where it may readily be shown to exist, by gently boiling in a tube a little of the clear colourless fluid from which the coagulated clot of fibrin and corpuscles has subsided. As soon as the temperature reaches about 170°, the albumen begins to coagulate, and on being boiled for a short time, separates entirely in the insoluble form.

467. It may also be precipitated from its solution in the serum, by adding to the clear fluid a few drops of dilute nitric or hydrochloric acid (136, 141). Acetic acid fails to precipitate it; but if ferrocyanide of potassium be added to the acidified solution, a dense white precipitate is produced, even when the albuminous liquid is very dilute.

468. When gently warmed with strong hydrochloric acid, albumen dissolves, forming a purple-coloured solution, in which respect it resembles fibrin and casein.

469. When moistened with strong nitric acid, albumen becomes yellow, owing to the formation of xanthoproteic acid ($2HO,C_{34}N_4H_{24}O_{12}$), which, together with oxalic acid (HO,C_2O_3), ammonia, nitric oxide (NO_2), and nitrogen, is always formed by the action of strong nitric acid on the compounds of protein. A familiar example of this occurs in the yellow stain caused on the skin by nitric acid.

470. It appears from the results of numerous analyses that the average amount of dry albumen present in healthy blood, is rather more than seventy parts in 1000 (573).

471. The composition of albumen is usually expressed by Mulder's formula ($C_{400}H_{310}N_{50}O_{120}S_2P$); but considerable uncertainty still hangs over the real nature of this class of bodies.* As the more important peculiarities of albumen have been already noticed in the chapter on morbid urine (133, 235, &c.), they need not be again described.

* The per-centage composition of the three so-called protein compounds, albumen, fibrin, and casein, is as follows:—

	Albumen.		Fibrin.		Casein.
Carbon	55.46	..	54.45	..	54.66
Hydrogen	7.20	..	7.07	..	7.15
Nitrogen	16.48	..	17.21	..	15.72
Oxygen	18.27	..	19.35	..	21.55
Sulphur	2.16	..	1.59	..	.92
Phosphorus	.43	..	.33		
	100.00		100.00		100.00

SECTION IV.

Fibrin.

472. This substance, of which muscular fibre is chiefly composed, is closely allied in chemical composition and general properties to albumen; and it is indeed not improbable that both are, in their chemical relations, merely modifications of the same compound, which from the circumstance of its being apparently the basis, not only of albumen and fibrin, but also of casein (625), and some other analogous substances, has been called *protein*, from πρωτεύω, I am first.*

473. While circulating in the vessels, the fibrin of the blood is held in a state of solution in the *liquor sanguinis*; but no sooner is the blood removed from the system, than it begins to separate in a solid state, after which it becomes quite insoluble in water. This solidification of the fibrin is the cause of the well-known phenomenon of coagulation which blood experiences almost immediately after it is drawn; and although the coagulum or clot contains the blood corpuscles in addition to the fibrin, these have merely been entangled in the network of coagulating fibrin, and do not themselves play any active part in the process of coagulation.

474. The coagulation of blood may be retarded, and even altogether prevented, by the presence of certain salts and other substances. The alkalies, for example, and their carbonates and acetates, entirely prevent it; and tolerably strong solutions of nitrate of potash, nitrate of lime, muriate of ammonia, and some other salts, retard it for a considerable time. The latter salt, indeed, gradually dissolves fibrin, after it has been allowed to coagulate. Most of the dilute acids, also, cause blood to retain its fluidity, though it becomes, under their influence, more viscous and syrupy in its consistence.

475. Contact with certain animal membranes also appears to exercise a retarding influence on the coagulation of the blood. When infused into the cellular tissue, it has been known to continue uncoagulated for some weeks; and even in a tied artery, it remains some hours without coagulating.

* See note to 471.

476. It appears from the experiments of M. Denis, that if moist fibrin be digested in a solution of nitrate of potash containing a little soda, at a temperature of about 100° F., it becomes gradually converted into a substance in almost every respect identical with albumen; being soluble in water, and coagulable by heat. This change is said to be most readily produced when the fibrin employed in the experiment has been obtained from venous blood, by allowing it to coagulate spontaneously; while if it is separated by agitation, or if the blood be arterial, it scarcely experiences any alteration in the saline solution.

477. Pure fibrin may be obtained without difficulty, by receiving the blood as it flows from the body, in a clean porcelain dish, and stirring it well for some little time with a glass rod; or the blood may be shaken with a few small fragments of lead, in a closed glass flask. The fibrin, as it coagulates, collects in loose fibrous masses round the rod or fragments of lead, coloured slightly red, owing to the imprisonment of a few corpuscles within the network of fibrin. These may be removed by tying the coagulum in a piece of fine muslin, and washing it under a stream of cold water until the mass becomes colourless. In this state, it still contains traces of fatty matter and inorganic salts, together with a considerable amount of water. To obtain the fibrin, therefore, in a state of perfect purity, the washed coagulum must be dried on a chloride of calcium bath at a temperature of about 250°, and the dry mass then reduced to fine powder in a mortar. The pounded fibrin may then be washed successively with alcohol, ether, and dilute hydrochloric acid; and, lastly, macerated with cold or lukewarm water, until all the soluble matter is removed; after which it may be dried as before at a temperature of about 250°.

478. If the blood from which we wish to extract the fibrin has already coagulated, the clot is first gently pressed between folds of bibulous paper, in order to squeeze out the greater part of the adhering serum, and then cut into thin shreds with a sharp knife. The finely divided clot is then washed in a muslin bag under a gentle stream of cold water, until it becomes colourless, by which means the imprisoned corpuscles are washed out of the fibrous mass. The latter is then dried, and reduced to powder, and subsequently purified by washing and drying in the manner above described (477).

479. Fibrin thus prepared, is a pale yellowish horny-looking substance, hard, brittle, and, if all traces of fat have been removed, transparent. It is perfectly tasteless, and insoluble in water, alcohol, and ether; if kept for a short time in water, however, it gradually softens, swells up, and reassumes the appearance it had previous to desiccation. When digested with acetic and most of the other acids, fibrin becomes gelatinous, and is in that state soluble in water. The acid solution, when treated with ferrocyanide of potassium, gives a copious white precipitate, similar to that caused in albuminous solutions. Like albumen, and the other modifications of protein, it forms, when gently warmed with strong hydrochloric acid, a purple-coloured solution. With nitric acid, also, fibrin behaves like the other protein compounds, forming the yellow xanthoproteic acid (469).

480. When examined under the microscope, coagulated fibrin appears to consist of a rude network of amorphous threads, together with detached aggregations of irregular form, similar to albumen.

481. The average proportion of dry fibrin present in healthy blood, appears to be rather more than two parts in a thousand (573).

SECTION V.

Extractive Matters.

482. Of the real chemical nature of the substances included under the name of extractive matters, little is yet definitely known, though they have frequently engaged the attention of chemists. It is probable, however, that further researches will ere long throw new light upon this at present obscure class of substances. They include all the undefined, uncrystallizable organic matters which are soluble in water; or, in other words, the extractive matters of the blood include all the organic substances contained in it, with the exception of the corpuscles, albumen, fibrin, and fatty matters.

483. Extractive matters are usually divided into *alcohol extractive* and *water extractive;* the first including that portion which is soluble both in water and alcohol; and

the latter, that which is soluble in water, and insoluble in alcohol. They are of a brown or yellowish colour, and are characterized by their solutions giving brown precipitates with acetate of lead, but none with bichloride of mercury. A solution of the alcohol extractive is precipitated by an infusion of galls, which reagent causes little or no change in the water extractive.

484. Traces of urea are probably always present in the blood, and would be contained in the alcohol extractive. The method of detecting it will be described further on (598).

485. The amount of extractive matters present in healthy blood, seems to vary from one to three parts in a thousand.

SECTION VI.

Fatty Matters.

486. Our knowledge of the fatty matters contained in the blood is at present far from being complete. They are usually divided into *oily fats* and *crystalline fats;* the first being soluble in cold alcohol, and the latter insoluble. The oily fats appear to consist chiefly of oleic ($HO,C_{44}H_{39}O_4$) and margaric ($2HO,C_{68}H_{66}O_6$) acids; the crystalline fatty matter is probably a mixture of serolin with traces of cholesterin ($C_{36}H_{32}O$), together with one or more solid fats containing phosphorus.

487. To obtain these fatty matters, a quantity of blood is evaporated to dryness on a water bath, and the dry residue, after being reduced to powder, is digested in hot ether, successive portions of which must be added as long as anything appears to be dissolved by it. The etherial solution is then evaporated to dryness on a water bath, and the residue, consisting of the mixed fats, treated with cold alcohol, which will dissolve out the oily fats, and leave the crystalline matters undissolved. The first may be obtained by evaporating the alcoholic solution on a water bath; and the undissolved crystalline fats may be dissolved in boiling alcohol, from which they will almost entirely separate, as the liquid cools, in the form of small crystalline scales.

488. The quantity of fatty matters present in healthy blood appears to vary from 1.5 to 2.5 in 1000 parts (573).

SECTION VII.

Fixed Saline Matters.

489. The ash left after the incineration of the dry residue of evaporated blood appears to contain the following substances—viz., the chlorides of sodium and potassium; the phosphates of lime, magnesia, and soda; the sulphates of potash and soda; and oxide of iron derived from the hæmatin (455). If the ash has been obtained by the incineration of the serum, traces of alkaline and earthy carbonates will probably be rendered apparent by the effervescence caused by the addition of an acid; but if the ash has been obtained by the incineration of the entire blood, no trace of carbonates will be observable on the addition of the acid. The cause of this appears to be, that some of the fatty matters present in the clot contain traces of phosphorus (486), which, during combustion, is converted into phosphoric acid (PO_5); and the phosphoric acid thus formed decomposes the small quantity of carbonates derived from the serum, converting them into phosphates.

490. The saline matters of the blood may be conveniently divided into the alkaline salts, which readily dissolve in water, and the earthy salts, which require an acid for their solution. The alkaline portion of the ash consists of the chlorides of sodium and potassium; the sulphates of potash and soda; and phosphate, with possibly traces of carbonate (489), of soda. The earthy or insoluble portion contains the phosphates of lime and magnesia; oxide of iron derived from the red colouring matter; and possibly a little earthy carbonate (489). The presence of the bases and acids contained in these several salts may be shown by the following experiments.

491. Digest from twenty to thirty grains of the ash in warm water, in order to dissolve out the alkaline salts, and filter the solution from the insoluble portion. The aqueous solution thus obtained may be first tested, retaining the earthy residue for subsequent examination (499).

492. If the aqueous solution is at all dilute, it should first be concentrated by evaporation. To a little of the concentrated solution add a slight excess of tartaric acid ($2HO,C_8H_4O_{10}$), and agitate the mixture with a glass rod.

A colourless crystalline precipitate of the bitartrate shows the presence of POTASH.

493. To another portion of the solution add a solution of bichloride of platinum ($PtCl_2$), and allow the mixture to evaporate to dryness, either spontaneously or at a very gentle heat. Minute yellow granular crystals of the double chloride of platinum and potassium ($KCl,PtCl_2$) will be found deposited, also showing the presence of POTASH. In addition to these will be seen long yellow needle-shaped crystals of the double chloride of platinum and sodium, proving the presence of SODA. If the bichloride of platinum has not been added in sufficient quantity to combine with the whole of the soda, a few detached cubical crystals of chloride of sodium will also be deposited, which may be proved to be such by their well-known taste.

494. The presence of SODA may also be shown by adding to a little of the strong aqueous solution a few drops of antimoniate of potash (KO,SbO_5), which will gradually cause a colourless crystalline precipitate of antimoniate of soda (NaO,SbO_5).

495. To another portion of the aqueous solution of the ash, add a solution of chloride of barium, or nitrate of baryta, as long as it causes any precipitate. The sulphuric, phosphoric, and (if any (489)) carbonic acids are thus thrown down in combination with baryta. The mixture containing the precipitate thus produced is now strongly acidified with hydrochloric or nitric acid, and warmed. If effervescence occurs on the addition of the acid, CARBONIC ACID is probably present. The presence of SULPHURIC ACID is shown by a portion of the precipitate (sulphate of baryta) proving insoluble in the acid.

496. Filter the acid mixture formed in (495), and neutralize the filtered liquid with ammonia. The phosphate of baryta ($2BaO,HO,PO_5$), which had been dissolved by the acid, is reprecipitated, indicating the presence of PHOSPHORIC ACID (498).

497. Acidify another portion of the aqueous solution of the ash with nitric acid; add a slight excess of nitrate of silver, and filter the liquid from the white precipitate occasioned by the silver salt. This precipitate may be proved to consist of chloride of silver (HYDROCHLORIC ACID), by being readily soluble in ammonia, and insoluble in nitric acid.

498. Accurately neutralize the acid solution formed in

(497), with dilute ammonia; the pale yellow phosphate of silver ($3AgO,PO_5$), which had been held in solution by the excess of acid, will now be precipitated, showing the presence of PHOSPHORIC ACID (496).

499. The earthy portion of the ash, which proved insoluble in water (491), may now be examined. It is to be dissolved in as small a quantity as possible of dilute hydrochloric acid, a gentle heat being applied if necessary. If effervescence occurs on the addition of the acid, CARBONIC ACID is present (489).

500. A little of the acid solution may now be nearly neutralized with dilute ammonia, which should not be added in sufficient quantity to cause any precipitate. The liquid is then tested with a drop or two of a solution of ferrocyanide of potassium, which will cause, either at once, or in the course of a few minutes, a blue colour, owing to the formation of the ferrocyanide of iron ($Fe_4 3FeCy_3$), showing the presence of IRON.

501. The rest of the acid solution of the earthy portion of the ash may now be supersaturated with ammonia, which will throw down a white gelatinous precipitate of earthy phosphates. A little of this precipitate may be examined under the microscope, when it will be found to consist chiefly of amorphous particles of phosphate of lime ($8CaO,3PO_5$), with a few crystals of the double phosphate of ammonia and magnesia ($2MgO,NH_4O,PO_5+12Aq$). The precipitate thrown down by the ammonia, may also be examined for LIME, MAGNESIA, and PHOSPHORIC ACID, by redissolving it in acetic acid, and testing the solution in the manner described in paragraphs 47, 71, &c.

502. The quantity of alkaline salts usually present in healthy blood varies from about seven to ten parts in 1000; and that of earthy salts from 0.5 to 1.5 in 1000 parts.

CHAPTER II.

QUANTITATIVE ANALYSIS OF BLOOD.

503. A complete quantitative analysis of the blood, including the separation from each other, and estimation of *all* the ingredients, would be, even if our knowledge and resources were much less limited than they are, in the

highest degree complicated and difficult; while at present it may be said to be altogether impracticable. For most purposes, however, a comparatively incomplete analysis, embracing the determination of the more important ingredients, is all that is required; and in the majority of cases, a knowledge merely of the proportion of fibrin, the corpuscles, and the solids contained in the serum, is what the medical practitioner chiefly requires.

504. I will first describe the mode of conducting such an analysis, by which the amount of water, corpuscles, fibrin, and solids contained in the serum, may, with very little difficulty, be ascertained; and subsequently go through a somewhat more complete scheme, by which, in addition to the above substances, the more important constituents of the serum may also be estimated. See sections 3 & 4.

505. When the blood intended for analysis can be collected in the proper vessels, as it flows from the body, the process is somewhat simpler than when it has been allowed to coagulate; and the results also are more accurate. As, however, this is frequently impracticable, I will also give the method by which the analysis of coagulated blood may be effected.

SECTION I.

Quantitative Analysis of uncoagulated blood, including the estimation of the water, corpuscles, fibrin, and the solid matters contained in the serum.

506. Before proceeding to collect the blood as it flows from the body, for the purpose of analysis, the experimenter should provide himself with three vessels, the exact weight of each of which is to be carefully ascertained and noted. These vessels are—1st. A six or eight ounce bottle provided with a stopper; this bottle should be perfectly clean and dry, and of known weight. Eight or ten small strips of thin sheet lead, about half an inch square, the weight of which should also be known, are put into the bottle, which will then be ready to receive the blood (507). This bottle is used for effecting the separation of the fibrin. 2nd. A small platinum or Berlin porcelain capsule, capable of holding from half an ounce to an ounce of water. This is used for estimating the proportion of water in the blood

(508). 3rd. A rather tall, upright beaker, or cylindrical glass, capable of holding about six ounces of water.

507. The blood may now be collected. About five or six ounces of the fluid are first poured into the bottle containing the fragments of lead, which should then be tightly closed with the stopper, and kept gently agitated for about a quarter of an hour, in order to allow the whole of the fibrin to coagulate, and attach itself to the pieces of lead (477, 506). This portion of blood we will call A (510).

508. Two or three drachms of blood are collected in the capsule, which is then again accurately weighed, and the weight of the empty capsule, previously ascertained (506), deducted from the gross weight, in order to determine the exact quantity of blood contained in it. It may then be placed on a water bath, and evaporated to dryness. This portion we will call B (514).

509. The beaker, or cylindrical glass, is to be nearly filled with the freshly drawn blood, covered with a glass plate, and set aside in a tolerably cool place for twenty-four hours; at the end of which time it will be found to be thoroughly coagulated, and separated into a firm clot and clear serum. This portion we will call C (516).

510. *Treatment of the portion A.*—When the blood has been gently shaken for about a quarter of an hour, immediately on being placed in the bottle (507), the fibrin will be found to have separated, and collected round the fragments of lead which had been previously introduced. The outside of the bottle is then cleaned with a wet cloth, and wiped dry.

511. The weight of the bottle, with its contents, is now taken, in order to ascertain the exact quantity of blood employed in the experiment, which is known by deducting from the gross weight that of the empty bottle and the lead, the difference being the weight of blood contained in it.

512. The stopper is now removed, and the contents of the bottle poured out into a small basin or saucer. The liquid portion is carefully poured off, and may be thrown away; after which the fibrin adhering to the lead is to be washed with a gentle stream of cold water, until it becomes colourless, in order to separate from it the whole of the corpuscles and serum. During the washing, the spongy aggregations of fibrin may be gently pressed occasionally between the fingers, care being taken that none of the

fragments are lost. When clean, the fibrin is to be placed in a small evaporating dish, and dried on a chloride of calcium bath, at a temperature of 220° or 230° until it ceases to lose weight. It is unimportant whether it is dried and weighed with the pieces of lead, or first separated from them, since the weight of the lead being known (506), may be deducted from the gross weight of the lead and fibrin, the difference being that of the fibrin.

513. The weight thus obtained represents the proportion of FIBRIN in the quantity of blood used in the experiment; the proportion in 1000 parts of blood may afterwards be ascertained by the following calculation :—

{Wt. of blood employed.} : {Wt. of fibrin obtained.} :: 1000 {Quantity of fibrin in 1000 parts of blood.}

514. *Treatment of the portion B.*—The capsule containing the portion B, after being accurately weighed (508), is allowed to remain on the water bath, (or still better, on a chloride of calcium bath, heated to about 220° or 230°), until it ceases to lose weight on being weighed at intervals of half an hour or an hour, care being taken to wipe the outside clean and dry each time. When the weight becomes constant, it may be concluded that the whole of the water has been expelled.

515. From the weight thus obtained, that of the empty capsule is now to be deducted; the difference being the weight of the ENTIRE SOLID MATTER contained in the quantity of blood operated on. The difference between the weight of this dry residue, and that of the blood before evaporation, or in other words, the loss which it has experienced during the evaporation, will then represent the amount of WATER contained in the quantity of blood employed in the experiment. The proportion of solid matter and of water present, in 1000 parts of the blood, may therefore be calculated in the following manner :—

For the Solid Matter.

{Wt. of blood evaporated.} : {Wt. of dry residue.} :: 1000 : {Proportion of solid matter in 1000 parts of the blood.}

For the Water.

{Wt. of blood evaporated.} : {Loss of wt. during evaporation.} :: 1000 : {Proportion of water in 1000 parts of the blood.}

516. *Treatment of the portion C.*—The third portion of blood which was collected in the beaker (509), is allowed to stand for about twenty-four hours, or until it separates into a firm clot and clear serum. Two or three drachms of the clear serum are carefully poured off from the clot into a small platinum or porcelain capsule, similar to that before used (506), the weight of which has been previously accurately noted. The capsule with the serum is now weighed, to ascertain the quantity of the latter employed in the experiment, and then evaporated to perfect dryness on a chloride of calcium bath, at a temperature of about 230° until it ceases to lose weight. The loss of weight which it experiences during evaporation, represents the amount of water in the quantity of serum used; while the weight of the dry residue shows the amount of solid matter contained in the same quantity of serum.

517. From the numbers now obtained, we are enabled to calculate the proportion of the solid matters of the serum in 1000 parts of blood, in the following manner. Knowing, as we do, the quantity of water in 1000 parts of the blood (515); and assuming (as we safely may) that the water of the blood exists wholly in the form of serum; knowing also the proportion of water and of solid matter contained in the serum (516); we may, from the quantity of water in the blood, estimate the quantity of solids held in solution in the serum, thus:—

$$\left\{\begin{array}{c}\text{Wt. of water}\\ \text{in the quan-}\\ \text{tity of serum}\\ \text{employed.}\end{array}\right\} : \left\{\begin{array}{c}\text{Wt. of solid mat-}\\ \text{ter in the quan-}\\ \text{tity of serum}\\ \text{employed.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Water in}\\ \text{1000 pts.}\\ \text{of the}\\ \text{blood.}\end{array}\right\} : \left\{\begin{array}{c}\text{Solids of}\\ \text{serum in}\\ \text{1000 pts. of}\\ \text{the blood.}\end{array}\right\}$$

518. We have now determined the proportion of water, fibrin, and solid matters of the serum, contained in the blood, and have only to ascertain the weight of the CORPUSCLES in order to complete the analysis. This is done by adding together the weights of the fibrin, and the solids of the serum, contained in 1000 parts of blood, and deducting the sum of them from the weight of the entire solid matter, which consists of fibrin, solids of the serum, and corpuscles; the difference therefore will represent the proportion of the latter in 1000 parts of the blood.

519. The several results now obtained may be recorded thus; and the numbers, when added together, should amount to within a fraction of 1000.

Water	.....
Corpuscles	.....
Fibrin	.....
Solid matters of serum	.....
	1000.00

SECTION II.

Quantitative Analysis of coagulated blood, including the estimation of the water, corpuscles, fibrin, and the solid matters contained in the serum.

520. The portion of blood intended for analysis, which may consist of about ten fluid ounces, should be collected in a weighed or counterpoised glass beaker, or other cylindrical vessel, and accurately weighed; or if it has been accidentally collected in any vessel of which the weight has not previously been determined, it may be weighed as before, and the weight of the containing vessel, ascertained after the blood has been removed, deducted from the gross weight; the difference being, of course, the weight of the blood employed. The blood, after being collected, is to be set aside in a tolerably cool place for about twenty-four hours, to allow it to coagulate; the top of the glass being covered with a glass plate or small dish, to preserve it from dust and prevent evaporation.

521. About two or three fluid drachms of the clear serum are to be drawn off with a pipette, or carefully poured off, into a small weighed platinum or porcelain capsule; after being accurately weighed, it is to be evaporated, until it ceases to lose weight, on a chloride of calcium bath, kept at a temperature of about 220°. When dry, the weight is noted; the loss during evaporation representing the amount of water in the quantity of serum operated on, and the weight of the dry residue being that of the solid matter contained in the same. The relative proportions of solid matter and water which form the serum, are thus ascertained.

522. While the evaporation of the serum (521) is going on, the examination of the rest of the coagulated blood may be proceeded with. The serum is first poured off from the clot with great care, avoiding the escape of any portion of the coagulum; the last portions of the liquid being removed

by means of a fine pointed pipette, or by introducing one end of a folded piece of bibulous paper, which will suck up the liquid until it is saturated, and may then be replaced by another. This serum, although it will probably not be wanted for any subsequent experiments, had better be for the present retained, in case of any accident happening to the portion already taken for evaporation (521).

523. The clot, thus separated from the greater part of the serum, is now to be divided, by means of a sharp knife, into two portions of equal weight; the weight of both being accurately made to correspond by weighing, and adding or taking off small slices, as necessity may require. When this is done, each portion will contain one half the fibrin and corpuscles of the quantity of blood operated on, together with a certain amount of serum. One of these equal portions we will call A, and the other B.

524. *Treatment of the portion of clot A.*—This is to be cut into thin shreds with a clean sharp knife, carefully avoiding the loss of any fragments of the coagulum. The finely sliced clot is then tied up in a piece of fine muslin, or calico, and washed under a gentle stream of cold water, with the assistance of occasional pressure between the fingers and thumb, until the whole of the serum and corpuscles are removed from the interstices of the coagulum, and the fibrin is left quite clean and colourless. It is then taken out of the muslin, and dried on a chloride of calcium bath, until it ceases to lose weight. The weight thus obtained represents the fibrin contained in half the clot, and when multiplied by two, gives the proportion of FIBRIN in the quantity of blood employed.

525. *Treatment of the portion of clot B.*—The weight of the portion B having been noted, it is to be evaporated to dryness on a chloride of calcium bath in a counterpoised or weighed capsule. The loss of weight which it experiences during evaporation, shows the quantity of water contained in half the clot, which, when multiplied by two, gives the amount of water present in the entire clot; while the weight of the solid residue, also multiplied by two, shows the quantity of solid matter which the entire clot contains.

526. From the data thus obtained, we are enabled to calculate the proportion of the several constituents, in the following manner. Having ascertained the weight of the whole solid matter of the clot (525), which consists of fibrin,

corpuscles, and solids contained in the portion of serum with which the clot is saturated, we first calculate how much of the weight is due to the solids of the serum. To do this, we assume that the whole of the water present in the clot is due to serum; then, knowing, from a previous experiment (521), the relative proportions of water and solid matter in the serum, and knowing also the quantity of water contained in the clot (525), we calculate the amount of solid matters in the clot, which belong to the serum, as follows:—

{Wt. of water in quantity of serum evaporated.} : {Wt. of solid matter in quantity of serum evaporated.} :: {Wt. of water in the entire clot.} : {Wt. of solid matters of serum, contained in the entire clot.}

527. The weight, thus calculated, of solid matters of serum present in the clot, is deducted from the weight of the entire solid matter contained in the clot (525), and the difference will represent the weight of the fibrin and corpuscles. Having, therefore, previously determined by a separate experiment (524), the amount of fibrin, we have only to deduct that number, in order to obtain the proportion of CORPUSCLES in the quantity of blood operated on.

528. Knowing now the amount of the fibrin and corpuscles, we can, by deducting their combined weights from that of the entire blood, learn the quantity of serum which it contained, since the blood is wholly composed of fibrin, corpuscles, and serum.

529. From the weight of serum thus obtained, assuming that the whole of the water in the blood is due to the serum, we can calculate that of the WATER and SOLID MATTERS OF THE SERUM contained in the entire blood, in the following manner, since we have before determined, by experiment (521), their relative proportions:—

For the Water.

{Wt. of serum which was evaporated to dryness.} : {Loss of wt. during evaporation.} :: {Wt. of serum in quantity of blood used.} : {Proportion of water in quantity of blood used.}

For the solid matters of the Serum.

{Weight of serum which was evaporated to dryness.} : {Weight of solid residue of serum after evaporation} :: {Weight of serum in quantity of blood used.} : {Wt. of solid matters of serum in quantity of blood used.}

530. We shall now, therefore, have ascertained the proportions of the four several constituents required, in the quantity of blood employed in the analysis—viz.

Water .....
Corpuscles .....
Fibrin .....
Solid matters contained in the serum

---

which, when added together, should amount very nearly to the weight of the blood used.

531. In order to determine the proportion of the several constituents present in 1000 parts of the blood, the following calculation will in each case be necessary.

$$\left\{\begin{array}{c}\text{Wt. of blood}\\ \text{employed}\\ \text{in the}\\ \text{analysis.}\end{array}\right\} : 1000 :: \left\{\begin{array}{c}\text{Weight of}\\ \text{each con-}\\ \text{stituent}\\ \text{obtained.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of that}\\ \text{constituent in}\\ \text{1000 parts of the}\\ \text{blood.}\end{array}\right\}$$

SECTION III.

Quantitative Analysis of uncoagulated blood, including the determination of the water, corpuscles, albumen, fibrin, alcohol extractive, water extractive, oily fats, crystalline or solid fats, and fixed saline matters.

532. The vessels required for this analysis are nearly the same as those already described in the shorter scheme of analysis (506)—viz.

1. A six or eight-ounce stoppered bottle, the weight of which is accurately known; and in which are placed a few small strips of thin sheet lead, the weight of which also is known.
2. A weighed platinum capsule or crucible, capable of holding rather more than an ounce of liquid; or, in default of this, a thin Dresden porcelain crucible, of about the same capacity. And
3. A tall upright beaker or cylindrical glass, capable of holding about eight ounces of liquid. The weight of this need not be taken.

533. The three vessels being in readiness, the blood is first to be collected. About six ounces of the fluid are

allowed to flow into the bottle, which should immediately be closed with the stopper, and gently shaken for a quarter of an hour or twenty minutes, at the end of which time the fibrin will be found to have separated from the liquid, and attached itself round the fragments of lead. This portion of blood we will call A (536).

534. About an ounce of blood is collected in the weighed capsule or crucible, and, after being weighed, for the purpose of ascertaining the exact quantity of blood employed, it is placed on a water bath, or chloride of calcium bath, and allowed to evaporate. This portion we will call B (539).

535. From six to eight ounces of blood are allowed to flow into the beaker, and set aside to coagulate in a tolerably cool place for about twenty-four hours. This portion we will call C (541).

536. *Treatment of the portion A.*—As soon as the fibrin is supposed to have separated completely from the blood, and become attached to the pieces of lead, the outside of the bottle is to be wiped clean and dry, and the whole is weighed; when the difference between the combined weights of the empty bottle and the lead, and that of the whole when filled, will represent the quantity of blood employed in the experiment.

537. The contents of the bottle are now to be emptied out into a small evaporating basin, and the fibrin is to be carefully separated from the fragments of lead, to which it adheres loosely. It is then washed under a gentle stream of cold water, from the serum and corpuscles with which it is saturated, carefully avoiding the loss of any particles of the fibrin.

538. When quite clean and colourless, the fibrin is placed in a platinum or thin porcelain crucible of known weight, and dried on a chloride of calcium bath, at a temperature of about 220° or 230°, until it ceases to lose weight. When dry, the weight is noted. As the fibrin, in its present state, contains traces of earthy phosphates, which add slightly to its apparent weight, it may now be incinerated in the crucible, until the ash becomes white or grey. The loss of weight which the dry fibrin experiences during incineration, represents the amount of pure FIBRIN in the quantity of blood that was contained in the bottle. The proportion present in 1000 parts of the blood may then be calculated as follows:—

$$\left\{\begin{array}{c}\text{Weight of}\\ \text{blood}\\ \text{employed.}\end{array}\right\} : \left\{\begin{array}{c}\text{Weight of}\\ \text{fibrin}\\ \text{obtained.}\end{array}\right\} :: 1000 : \left\{\begin{array}{c}\text{Proportion of}\\ \text{fibrin in 1000}\\ \text{pts. of blood.}\end{array}\right\}$$

539. *Treatment of the portion B.*—This portion of the blood, after being weighed, is allowed to remain on a chloride of calcium bath, heated to about 220°, until it ceases to lose weight; when it may be concluded that the whole of the water has been expelled. When this is the case, the weight is noted, and the proportion of WATER and SOLID MATTERS OF THE BLOOD, contained in 1000 parts of the fluid, calculated as follows:—

For the Water.

$$\left\{\begin{array}{c}\text{Wt. of blood}\\ \text{evaporated}\\ \text{to dryness.}\end{array}\right\} : \left\{\begin{array}{c}\text{Loss of wt.}\\ \text{during}\\ \text{evaporation.}\end{array}\right\} :: 1000 : \left\{\begin{array}{c}\text{Proportion of}\\ \text{water in 1000}\\ \text{pts. of blood.}\end{array}\right\}$$

For the Solid Matter.

$$\left\{\begin{array}{c}\text{Wt. of blood}\\ \text{evaporated}\\ \text{to dryness.}\end{array}\right\} : \left\{\begin{array}{c}\text{Weight of}\\ \text{dry}\\ \text{residue.}\end{array}\right\} :: 1000 : \left\{\begin{array}{c}\text{Proportion of solid}\\ \text{matter in 1000}\\ \text{pts. of blood.}\end{array}\right\}$$

540. The dry residue (539), after being weighed, is to be incinerated in the capsule or crucible, until the whole of the charcoal of the organic matter is burnt away, and the ash becomes of a pale red colour. The weight of the ash thus obtained, shows the amount of FIXED SALINE MATTER in the quantity of blood evaporated; and from this, the proportion contained in 1000 parts of the blood may be thus estimated:—

$$\left\{\begin{array}{c}\text{Weight of}\\ \text{blood}\\ \text{evaporated.}\end{array}\right\} : \left\{\begin{array}{c}\text{Wt. of ash}\\ \text{after in-}\\ \text{cineration.}\end{array}\right\} :: 1000 : \left\{\begin{array}{c}\text{Proportion of fixed}\\ \text{saline matter in}\\ \text{1000 pts. of blood.}\end{array}\right\}$$

541. *Treatment of the portion C.*—This portion of blood is allowed to stand for about twenty-four hours, in order that it may coagulate spontaneously, and divide itself into a firm clot and perfectly clear serum.

542. Two or three fluid drachms of the serum are first removed from the surface, and placed in a small platinum or porcelain capsule; the exact quantity of serum taken, being ascertained by again weighing the capsule and its contents. It is then placed on a chloride of calcium bath, and, when perfectly dry, again weighed, in order to determine the relative proportions of solid matter and water in the serum; the weight of the dry residue, and the amount of loss during evaporation, representing respectively the

proportion of solids and of water in the quantity of serum employed.

543. From the numbers thus obtained we are able (assuming that the whole of the water in the blood exists in the form of serum) to estimate the quantity of SERUM contained in 1000 parts of the blood, since we have before ascertained the amount of water in 1000 parts of blood (539), and also the relative proportion which the serum bears to the water contained in it (542), thus :—

Wt. of water in the quantity of serum that was evaporated to dryness.	:	Weight of serum which was evaporated to dryness.	::	Weight of water in 1000 parts of blood.	:	Weight of serum in 1000 parts of blood.

544. Another portion of the clear serum, weighing exactly 500 grains, is now to be weighed out in a platinum or porcelain capsule, and evaporated to dryness on a water bath. This will serve for the estimation of the albumen, oily and crystalline fats, and alcohol and water extractives.

545. The dry residue is to be carefully detached, by means of a knife, from the capsule, which should be placed on a sheet of clean paper, in order to catch any fragments that may be projected over the sides of the capsule. The dry mass is then reduced to fine powder in a mortar, also placed on a sheet of paper, carefully avoiding the loss of any of the particles. The powder is then digested in successive small quantities of boiling ether, which may be poured off, as the insoluble matter readily subsides to the bottom of the capsule (547).

546. The etherial solution thus obtained, containing the fatty matters, both oily and crystalline, is to be evaporated in a capsule of known weight, on a water bath, until the whole of the ether is expelled. The residue is now weighed, by which the whole amount of fatty matters is ascertained. It is then treated with cold alcohol, which will dissolve out the oily fat. The weight of the residue left on evaporating the alcoholic solution, therefore, will represent the amount of OILY FAT in 500 grains of serum; and the difference between this and the weight of the whole fatty matter shows the quantity of SOLID or CRYSTALLINE FATTY MATTER in the same serum. The proportion of each of these, which is contained in 1000 parts of blood, may then be calculated as follows :—

For the oily fat.

$$500 : \left\{\begin{array}{c}\text{Wt. of oily}\\ \text{fat in 500}\\ \text{grs. of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Wt. of serum}\\ \text{in 1000 parts}\\ \text{of blood.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of oily}\\ \text{fat in 1000 parts}\\ \text{of blood.}\end{array}\right\}$$

For the crystalline fatty matter.

$$500 : \left\{\begin{array}{c}\text{Wt. of crystal-}\\ \text{line fat in 500}\\ \text{grs. of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Wt. of serum}\\ \text{in 1000 parts}\\ \text{of blood.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of crystal-}\\ \text{line fat in 1000 parts}\\ \text{of blood.}\end{array}\right\}$$

547. The residue which proved insoluble in the ether (545), is now to be warmed, in order to expel any traces of ether that may still be present, and then treated with boiling water, which will coagulate the albumen, thus rendering it insoluble; while the extractive matters are dissolved out (549). The mixture is then filtered, and the insoluble residue of albumen washed on the filter with hot water, until a drop of the filtered liquid causes no precipitate, or merely a very slight opalescence, when tested with a solution of nitrate of silver.

548. The albumen, thus freed from extractive and soluble saline matters, is to be dried and weighed; but as some traces of inorganic matter are always associated with the albumen, the dry mass is to be incinerated, and the weight of the ash deducted from it, when the difference will represent the amount of pure ALBUMEN in 500 grains of serum. The proportion in 1000 parts of blood may then be calculated, thus:—

$$500 : \left\{\begin{array}{c}\text{Wt. of albu-}\\ \text{men in 500}\\ \text{grs. of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Wt. of serum}\\ \text{in 1000 parts}\\ \text{of blood.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of albu-}\\ \text{men in 1000 parts}\\ \text{of blood.}\end{array}\right\}$$

549. The aqueous solution filtered from the albumen (547), containing the extractive matters and soluble salts, is now to be evaporated to dryness in a capsule of known weight, on a water bath, and weighed. The dry residue is then treated with alcohol, which should be poured off and renewed as long as anything continues to be dissolved by it. The alcoholic solution is evaporated to dryness on a water bath, and weighed; it is then incinerated, and the weight of the ash is deducted from that of the dry mass previous to incineration. The number thus obtained represents the amount of ALCOHOL EXTRACTIVE in 500 grains of serum, which may be reduced to the proportion in 1000 parts of blood, as follows:—

$$500 : \left\{\begin{array}{c}\text{Wt. of alcohol}\\ \text{extract. in 500}\\ \text{grs. of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Wt. of serum}\\ \text{in 1000 parts}\\ \text{of blood.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of alcohol}\\ \text{extract. in 1000 parts}\\ \text{of blood.}\end{array}\right\}$$

550. The portion of the dry residue which proved insoluble in alcohol (549), is now to be dried, weighed, and ignited; the weight of the ash being deducted from that of the dry mass previous to ignition. This will give the weight of the WATER EXTRACTIVE in 500 grains of serum, from which the quantity in 1000 parts of blood may be estimated as in the former cases:—

$$500 : \left\{\begin{array}{c}\text{Wt. of water}\\ \text{extract. in 500}\\ \text{grs. of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Wt. of serum}\\ \text{in 1000 parts}\\ \text{of blood.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of water}\\ \text{extract. in 1000 parts}\\ \text{of blood.}\end{array}\right\}$$

551. We shall now have estimated the proportion of water, and of all the solid constituents, with the exception of the CORPUSCLES. The proportion of these is known by deducting the sum of the several solid matters, the weights of which are already determined (including everything but the corpuscles), from the weight of the whole solid matter contained in 1000 parts of blood (539), the difference representing the proportion of corpuscles present in 1000 parts of the fluid.

552. The results of the analysis may then be recorded as follows, and should, when added together, amount to a fraction less than 1000.

Water .....
Corpuscles .....
Albumen .....
Fibrin .....
Alcohol extractive .....
Water extractive .....
Oily fats .....
Crystalline or solid fats .....
Fixed saline matter .....

SECTION IV.

Quantitative analysis of coagulated blood, including the estimation of the water, corpuscles, albumen, fibrin, alcohol extractive, water extractive, oily fats, crystalline and solid fats, and fixed saline matters.

553. About ten or twelve ounces of blood having been collected in a beaker, or other rather tall vessel of known

weight, it is to be covered over to prevent evaporation, and set aside in a cool place for about twenty-four hours, when it will be found to have separated into a firm clot and clear serum. The weight of the whole blood is to be accurately determined either before or after coagulation. Three or four fluid drachms of the clear serum are first drawn off with a pipette, weighed in a platinum or porcelain crucible of known weight, evaporated to dryness on a chloride of calcium bath, and the weight of the dry residue ascertained. The loss of weight during evaporation representing the water, we thus determine the relative proportions of SOLID MATTER AND WATER IN THE SERUM.

554. The dry residue of the serum (553) is now to be incinerated, until the ash becomes white or grey ; and the latter is then weighed. The proportion of FIXED SALINE MATTER OF THE SERUM is thus ascertained.

555. The greater part of the remaining clear serum is now to be carefully poured off from the coagulum, and retained for further examination (565). The last portions of the liquid are to be removed by means of a fine pipette, or by sucking it up with little rolls of bibulous paper (522), carefully avoiding the removal of any portions of the clot.

556. The coagulum, thus separated as completely as possible from the serum, is now to be divided into two portions of exactly equal weight (523), each of which will then contain one half of the fibrin and corpuscles present in the quantity of blood operated on, together with a certain amount of serum. These two equal portions we will distinguish as A and B.

557. *Treatment of the portion of clot A.*—This portion of the clot is to be cut with a sharp knife into fine slices, carefully avoiding any loss. These are then tied up in a piece of fine muslin, and washed, until they become quite colourless, when it may be concluded that the whole of the corpuscles and serum has been washed out. The fibrin is now dried on a chloride of calcium bath at a temperature of about 230°, and weighed. It still, however, contains traces of earthy salts, the quantity of which is known by incinerating the dry fibrin, and deducting from it the weight of the ash. The loss of weight during incineration represents the quantity of fibrin contained in one half the clot, and this, when multiplied by two, gives the proportion of FIBRIN in the quantity of blood employed.

558. *Treatment of the portion of clot B.*—This half of the clot is to be weighed in a capsule of known weight, and evaporated to dryness on a chloride of calcium bath. The residue is now weighed, and the loss of weight during evaporation will show the amount of water present in half the clot; which, when multiplied by two, gives the quantity of WATER CONTAINED IN THE ENTIRE CLOT; while the weight of the dry residue, also multiplied by two, represents the amount of SOLID MATTER PRESENT IN THE ENTIRE CLOT.

The dry residue of B is to be retained for subsequent incineration (563).

559. Having thus determined the weight of the whole solid matter of the clot, which consists of fibrin and corpuscles, together with the solids contained in the portion of serum with which the clot is saturated; we now have to calculate how much of the weight is due to the solids of the serum. Assuming that the whole of the water present in the clot is due to the serum, and knowing the relative proportions of water and solid matter in the serum (553); knowing also the quantity of water present in the entire clot (558); the amount of solid matters in the clot which belong to the serum, may be calculated in the following manner:—

$$\left\{\begin{array}{c}\text{Wt. of water}\\ \text{in quantity}\\ \text{of serum}\\ \text{evaporated.}\end{array}\right\} : \left\{\begin{array}{c}\text{Wt. of solid}\\ \text{matter in}\\ \text{quantity of}\\ \text{serum evap.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Wt. of}\\ \text{water}\\ \text{in entire}\\ \text{clot.}\end{array}\right\} : \left\{\begin{array}{c}\text{Wt. of solid mat-}\\ \text{ters of serum,}\\ \text{contained in the}\\ \text{entire clot.}\end{array}\right\}$$

560. The weight of solid matters of the serum thus found to be present in the clot, is to be deducted from the weight of the entire solid matter of the clot (558), when the difference will represent the weight of the fibrin and corpuscles; the weight of the fibrin, however, having been already ascertained by a separate experiment (557), we have merely to deduct that amount, in order to determine the proportion of CORPUSCLES in the quantity of blood employed in the analysis.

561. Now since the blood may be said to consist wholly of fibrin, corpuscles, and serum; and knowing, as we do (557, 560), the weight of the fibrin and the corpuscles; we can, by deducting the combined weights of those two substances from the weight of the entire blood, learn the proportion of SERUM in the quantity of blood operated upon.

562. But we have before determined the relative proportions of solid matter and water in the serum (553); so that, assuming that the whole water of the blood is due to the serum, we can, from the quantity of serum obtained in paragraph 561, estimate the proportion of WATER in the blood, thus :—

Wt. of serum which was evaporated to dryness.	:	Loss of wt. during evaporation, (water.)	::	Wt. of serum in quantity of blood used.	:	Proportion of water in quantity of blood used.

563. The dry residue of the portion of the clot B (558) is now to be incinerated. The weight of the ash thus obtained, multiplied by two, will give the amount of the inorganic salts contained in the clot. A certain portion of this weight, however, is due to the salts of the serum which was contained in the clot, the amount of which may be learnt by the following calculation, since we have before determined the relative proportions of solid matter and inorganic ash in the serum (553, 554).

Wt. of solid matter in quantity of serum evaporated to dryness.	:	Wt. of ash derived from same quantity of serum.	::	Wt. of solid matters of serum in the clot.	:	Wt. of ash derived from the serum in the clot.

By deducting this number from the weight of the ash of the whole clot, we ascertain the amount of inorganic saline matter derived from the fibrin and corpuscles.

564. In order to determine the whole amount of fixed salts in the blood, we must now reckon how much the whole of the serum contains. This is done as follows :—

Weight of serum evaporated to dryness.	:	Wt. of ash from same quantity of serum.	::	Wt. of serum in the entire blood.	:	Weight of fixed salts in the whole serum.

By adding together the ash of the serum thus obtained, and that derived from the fibrin and corpuscles (563), we ascertain the proportion of FIXED SALINE MATTER in the quantity of blood employed in the analysis.

565. *Estimation of the albumen, extractives, and fatty matters.* Five hundred grains of the clear serum (555) are to be weighed out in a platinum or porcelain evaporating basin, and evaporated to dryness on a water bath. The basin is then placed on a clean sheet of paper, and the dry residue carefully detached from it, and reduced to fine powder in a mortar, taking care that none of the small

fragments are lost. The pulverized residue is then treated with successive small portions of boiling ether, until all the soluble matter is removed (545).

566. The etherial solution is now to be evaporated to dryness in a capsule of known weight on a water bath, and the residue of fatty matter weighed. This is then digested with cold alcohol, in order to dissolve out the oily fat, which will be left as a residue after evaporating the alcoholic solution to dryness. The weight of this OILY FAT is then taken; and the difference between this weight and that of the whole fatty matter, left on evaporating the etherial solution, will represent the quantity of CRYSTALLINE OR SOLID FAT contained in five hundred grains of serum.

567. The proportions of these fats present in the whole quantity of blood employed in the analysis, are calculated as follows:—

For the oily fat.

500 : { Wt. of oily fat in 500 grs. of serum. } :: { Wt. of serum in quantity of blood used (561). } : { Proportion of oily fat in quantity of blood used. }

For the crystalline fat.

500 : { Wt. of crystalline fat in 500 grs. of serum. } :: { Wt. of serum in quantity of blood used (561). } : { Propor. of crystalline fat in quantity of blood used. }

568. The portion of the residue which proved insoluble in ether (565), is now warmed to expel the still adhering ether, and then digested in boiling water, which will dissolve out the extractive matters, leaving the coagulated albumen undissolved. The latter is separated from the solution by filtration, and washed with warm water until the washings cause merely a slight opalescence when tested with nitrate of silver. The albumen is dried, weighed, and the dry mass then incinerated, in order to determine the amount of inorganic ash with which it is associated. The ash is weighed, and its weight deducted from that of the dry mass previous to incineration. The difference between the two weighings represents the quantity of ALBUMEN in 500 grains of serum. The proportion of albumen contained in the whole quantity of blood may then be estimated as follows:—

500 : { Wt. of albumen in 500 grains of serum. } :: { Weight of serum in quantity of blood used. } : { Proportion of albumen in quantity of blood used. }

569. The solution filtered from the albumen, and containing the extractive matters and soluble salts, is evaporated to dryness in a capsule of known weight, on a water bath, and weighed. The weight of the evaporated residue having been noted, it is exhausted with alcohol, and the alcoholic extract is evaporated to dryness on a water bath, and weighed; it is then incinerated, and the weight of the ash is deducted from that of the dry mass previous to incineration. The weight thus obtained represents the quantity of ALCOHOL EXTRACTIVE in five hundred grains of serum, which may be reduced to the proportion present in the whole quantity of blood used, in the following manner:

$$500 : \left\{\begin{array}{c}\text{Wt. of alcohol extract. in 500 grs. of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Weight of serum in quantity of blood used.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of alcohol extractive in quantity of blood used.}\end{array}\right\}$$

570. The portion of the residue which the alcohol failed to dissolve (569), is now to be dried, weighed, and incinerated; the weight of the ash being then deducted from that of the dry mass previous to incineration. This will give the weight of WATER EXTRACTIVE contained in five hundred grains of serum, from which the proportion present in the whole quantity of blood used may be estimated as before:—

$$500 : \left\{\begin{array}{c}\text{Wt. of water extractive in 500 grains of serum.}\end{array}\right\} :: \left\{\begin{array}{c}\text{Weight of serum in quantity of blood used.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of water extractive in quantity of blood used.}\end{array}\right\}$$

571. The results of the analysis may then be summed up as follows; and if the experiments have been conducted with care, the numbers will, when added together, coincide very nearly with the whole quantity of blood employed in the analysis.

Water .....
Corpuscles .....
Albumen .....
Fibrin .....
Alcohol Extractive .....
Water Extractive .....
Oily Fats .....
Crystalline or Solid Fats .....
Fixed Saline Matters .....

572. In order to reduce these several amounts to the proportion contained in 1000 parts of the blood, the following calculation must be made in each case:

$$\left\{\begin{array}{c}\text{Wt. of}\\ \text{blood}\\ \text{used.}\end{array}\right\} : 1000 :: \left\{\begin{array}{c}\text{Wt. of each}\\ \text{constituent}\\ \text{obtained.}\end{array}\right\} : \left\{\begin{array}{c}\text{Proportion of that con-}\\ \text{stituent in 1000 parts}\\ \text{of blood.}\end{array}\right\}$$

The several quantities thus obtained should, when added together, amount to a fraction less than one thousand.

SECTION V.

Average composition of Healthy Blood.

573. The following analyses will serve to show the usual composition of healthy blood.

Analysis I. Healthy Venous Blood. (Dumas.)

130 Clot	Fibrin		3
	Globules	Hæmatin	2
		Albuminous matter	125
870 Serum	Water		790
	Albumen		70
	Oxygen, Nitrogen, Carbonic acid		
	Extractive matter, Phosphorized fat, Cholesterin, Serolin, Oleic and margaric acids, Chlorides of sodium and potassium, Muriate of ammonia, Carbonates of soda, lime, and magnesia, Phosphates of soda, lime, and magnesia, Sulphate of potash, Lactate of soda, Salts of the fatty acids, Yellow colouring matter		10
			1000

Analysis II. (*Simon.*)

Water	795.278
Fibrin	2.104
Fat	2.346
Albumen	76.600
Globulin	103.022
Hæmatin	6.209
Extractive matter and salts	12.012

Analysis III. & IV. (*Becquerel and Rodier.*)

Showing the mean composition of male and female blood.

	Male.		Female.
Density of defibrinated blood	1060.00	...	1057.50
Density of serum	1028.00	...	1027.40
Water	779.00	...	791.10
Fibrin	2.20	...	2.20
Fatty matters	1.60	...	1.62
Serolin	0.02	...	0.02
Phosphorized fat	0.49	...	0.46
Cholesterin	0.09	...	0.09
Saponified fat	1.00	...	1.04
Albumen	69.40	...	70.50
Blood corpuscles	141.10	...	127.20
Extractive matters and salts	6.80	...	7.40
Chloride of sodium	3.10	...	3.90
Other soluble salts	2.50	...	2.90
Earthy phosphates	0.33	...	0.35
Iron	0.57	...	0.54

Analysis V. (*Lecanu.*)

Water	790
Solid residue	210
Fibrin	3
Organic residue of serum	72
Inorganic ditto	8
Blood corpuscles	127

Analysis VI. (*Enderlin.*)

Showing the composition of the ash of human blood.

Tribasic phosphate of soda ($3NaO,PO_5$)	22.100	83.746	Soluble salts.
Chloride of sodium	54.769		
Chloride of potassium	4.416		
Sulphate of potash	2.461		
Phosphate of lime	3.636	15.175	Insoluble salts.
Phosphate of magnesia	0.769		
Peroxide of iron and phosphate of iron	10.770		
	98.921		

CHAPTER III.

MORBID BLOOD.

574. The chemistry of the blood in its pathological conditions has, until within the last few years, occupied very little attention from the chemist or physician, the consequence of which has been, that much ignorance has always prevailed, and, it is to be feared, still prevails, among the great mass of the profession, respecting this important and interesting subject of inquiry. It is not unreasonable to anticipate that the fresh knowledge which we are now almost daily acquiring in this and other kindred branches of physiological and pathological chemistry, will gradually lead to highly important and beneficial practical results, in the more enlightened treatment of disease, and the more ready mitigation of suffering.

575. The variations which are found to occur in the chemical composition of morbid blood may be divided into two classes:—

1st. Those in which, so far as we are aware, no abnormal matter, not contained in healthy blood, is present; but

in which one or more of the normal constituents of healthy blood exists in a greater or less proportion than in the healthy fluid.

2nd. Those in which we can detect the presence of one or more abnormal matters which are not found in healthy blood.

576. To the first of these classes belong those cases in which we find an excess or deficiency of water, corpuscles, albumen, fibrin, fatty matters, cholesterin, urea, or inorganic salts; and to the second, those in which either sugar, biliary matter, pus, entozoa, or other abnormal matter, can be detected. I will briefly notice each of these morbid conditions of the blood, together with the mode of examination, whether chemical or microscopic, which will be found most readily applicable to each.

CLASS I.—*Morbid blood in which no abnormal matter is present.*

SECTION I.

Blood containing an excess or deficiency of Water.

577. The proportion of water even in healthy blood appears to vary considerably, so that it is difficult to say what may be considered as the normal amount. The usual average, however, contained in human blood, seems to be from 790 to 800 in 1000 parts.

578. In some forms of disease, as, for example, anæmia and chlorosis, the proportion of water is usually much greater, and has been known to amount to upwards of 900 parts in 1000. In certain other pathological conditions, on the contrary, the blood is found to contain considerably less water than is present in the healthy fluid; in cholera, for instance, where the blood is so rich in solid matter as almost to resemble jelly in appearance, it has been known to contain not more than 480 parts of water in 1000.

579. The proportion of water present in any specimen of blood may readily be ascertained by evaporating a known weight of the fluid in a weighed or counterpoised capsule, on a chloride of calcium bath, heated to about 220° or 230°, until it ceases to lose weight. The loss of weight during the evaporation will then represent the proportion of water

in the quantity of blood employed, which may be reduced to 1000 parts, as follows:

$$\left\{\begin{array}{c}\text{Wt. of}\\ \text{blood}\\ \text{evaporated.}\end{array}\right\} : \left\{\begin{array}{c}\text{Loss of weight}\\ \text{during evaporation.}\end{array}\right\} :: 1000 : \left\{\begin{array}{c}\text{Proportion of}\\ \text{water in 1000}\\ \text{parts of blood.}\end{array}\right\}$$

SECTION II.

Blood containing an excess or deficiency of Corpuscles.

580. The average proportion of corpuscles contained in healthy human blood, appears to be from 120 to 130 parts in 1000. In disease, especially in some forms of fever, it sometimes increases considerably, and has been known to amount to 185 parts in 1000; while in anæmia, and certain other affections long known as being attended with great poorness of blood, the proportion of corpuscles frequently does not amount to more than 60 or 70, and has been known to be as low as 21 in 1000 parts.

581. The direct determination of the weight of the corpuscles is a matter of considerable difficulty, so that they are generally estimated by deducting the combined weights of the water, fibrin, and solid matters of the serum, which are easily determined experimentally, from that of the entire blood, in the manner described in paragraphs 518, 527, &c.

582. According to Figuier, their weight may be determined with considerable accuracy by mixing the blood, previously weighed and defibrinated by agitation, with fragments of lead (507), with about twice its bulk of a strong solution of sulphate of soda (specific gravity 1.13), filtering through a filter of known weight (Prac. Chem. 641), and washing the corpuscles on the filter with a little more of the saline solution (456). When most of the liquid has drained through, the filter with its contents is dipped in boiling water, and allowed to remain in it some little time, in order to dissolve out the salt; while the organic matter of the corpuscles is coagulated by the heat, and thus rendered insoluble. The filter with the corpuscles is then dried at 212°, weighed, and the weight of the dry filter, previously determined, being deducted, the difference will represent the weight of the corpuscles contained in the quantity of blood operated on.

583. The microscopic appearance of the corpuscles is also not unfrequently found to vary under the influence of disease, the modifications of form occurring occasionally in the living body, but more frequently after death. Most of these changes are due to the phenomena of endosmosis or exosmosis, already referred to (456). Thus they are sometimes met with having a more or less globular form, owing to the entrance of fluid less dense than the serum of healthy blood; at other times they are found to have a wrinkled or indented outline, similar to that which the healthy corpuscle assumes when placed in contact with strong saline solutions of high specific gravity. (See fig. 60, page 122).

584. In examining the blood corpuscles under the microscope, with a view to detecting any abnormal appearance as a consequence of disease, it must be borne in mind that these and other analogous changes in the form of the corpuscle, are artificially induced by the action of water or other liquids with which they may have been allowed to come in contact; such contact should therefore be carefully avoided. The wrinkled appearance is sometimes caused also by the concentration of the serous fluid, owing to spontaneous evaporation (456).

SECTION III.

Blood containing an excess or deficiency of Albumen.

585. The average proportion of albumen in healthy blood appears to lie between 70 and 75 parts in 1000; while in disease it is occasionally (as in cholera) as high as 131, and (as in Bright's disease) as low as 55 parts in 1000.

586. The amount of albumen in any specimen of blood may be ascertained in the manner described in paragraphs 547, 568; or a weighed portion of serum may be carefully neutralized with dilute hydrochloric acid, diluted with an equal bulk of water, and boiled for about a quarter of an hour. The coagulum of albumen is then separated by filtration; washed with a little boiling ether in order to remove the fat; dried at 212°, and weighed before and after

incineration; the difference between the two weighings being the weight of albumen in the quantity of serum used (548).

587. The quantitative estimation of the other constituents of the blood may, if necessary, be conducted as in the case of healthy blood (503 &c.).

SECTION IV.

Blood containing an excess or deficiency of Fibrin.

588. Healthy human blood usually contains from two to three parts of fibrin in 1000; while in disease it has been found to vary from a mere trace to upwards of ten parts in 1000; a considerable increase in the amount being usually found in most forms of inflammatory disease.

589. The peculiar appearance frequently to be seen after coagulation, in blood taken from the body during certain pathological conditions, long known as the *buffy coat*, is caused by the upper portion of the clot being composed almost entirely of fibrin, or of some modification of protein closely allied to it, unmixed with the red corpuscles. This may be owing either to the blood-corpuscles subsiding in the liquid more rapidly than in ordinary blood, or to the fibrin coagulating more slowly; in either case the upper portion of the coagulated fibrin would be more or less free from the corpuscles to which the red colour of the ordinary clot is due. The blood in which the buffy coat is found to occur is, in most cases, rather rich in fibrin, and it was formerly regarded as a sure sign of inflammation; an opinion which has since been proved to be altogether erroneous (454).

590. The proportion of fibrin may be readily determined, either in coagulated or freshly drawn blood, in the manner already described. For freshly drawn blood, see paragraph 510 &c., and for coagulated blood, see paragraph 524 &c.

The quantitative estimation of the other ingredients may also, if necessary, be conducted in the same manner as in healthy blood (503 &c.).

SECTION V.

Blood containing an excess of Fatty Matter.

591. The average amount of fat in healthy blood appears to be something more than two parts in a thousand. The whole of the oily fat probably exists in combination with potash or soda, forming a kind of soap; so that in the healthy fluid no oil globules can be detected.

592. In certain pathological conditions we occasionally meet with blood containing a considerable quantity of free fat, which is held in suspension, in the form of minute globules in the serum, giving that fluid a more or less opaque or milky appearance. In this form of blood, which, from its peculiar appearance, has been called *milky blood*, may be seen, with the help of the microscope, innumerable fat globules, which may be readily distinguished by their bright centres, and black well-defined outlines (Fig. 63). They may be separated by agitating the blood with a little ether, which will readily dissolve them.

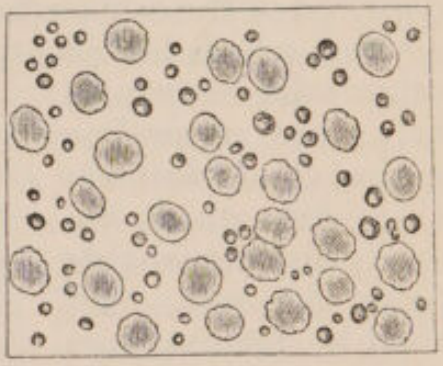

Fig. 63. Fat in blood.

593. The amount of fat in any specimen of blood, may be determined by evaporating to dryness a known weight of the fluid, pounding the dry residue, and boiling it with successive small quantities of ether. The etherial solution of the fat thus obtained is evaporated to dryness in a counterpoised capsule, and weighed; its weight representing the proportion of fat in the quantity of blood employed.

594. The quantitative determination of the other constituents of the blood may, if required, be effected in the same manner as in the healthy fluid (503 &c.)

SECTION VI.

Blood containing an excess of Cholesterin.

595. Minute traces of cholesterin appear to be always present in healthy blood, though some observers have

failed in their endeavours to detect it. The amount, however, in certain forms of disease, not unfrequently rises as high as 0.15 to 0.20 in 1000 parts; and in one case of so called milky blood, Lecanu found not less than 1.08 in 1000.

596. When an excess of cholesterin is suspected to be present in any specimen of blood, it may be separated and estimated with tolerable accuracy in the following manner. A known weight of the blood is evaporated to dryness on a water bath, and the dry residue, after being reduced to fine powder in a mortar, is digested for a few hours in ether, the solvent action being assisted by occasional boiling. In this way the cholesterin, together with the other fatty matters, is dissolved, and may be obtained by evaporating the etherial solution on a water bath. The residue is then deprived of the oily portion of the fat, by digestion with cold alcohol, which leaves undissolved the cholesterin, with the other solid fatty matters; the crystalline scales of cholesterin (Fig. 64), which are easily distinguishable from the rest, may then be, for the most part, mechanically separated with the point of a knife. Their weight may then, after drying, be ascertained, if necessary.

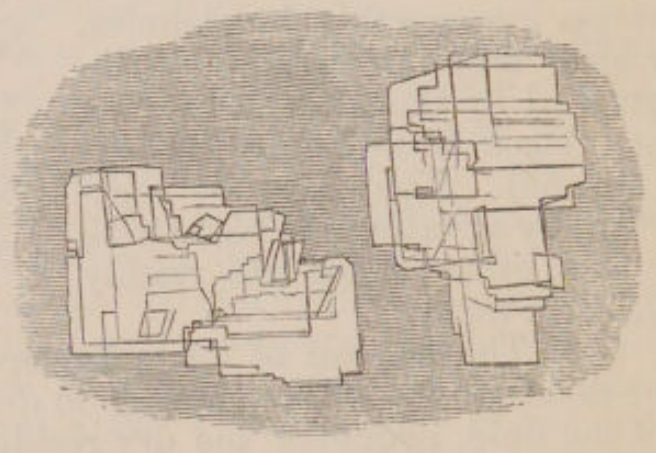

Fig. 64. Cholesterin.

597. The quantitative estimation of the other constituents may be conducted as in the case of healthy blood (503, &c.).

SECTION VII.

Blood containing an excess of Urea.

598. Minute traces of urea are probably always present in healthy blood (484), though the amount is so small as to be incapable of determination, unless considerable quantities of blood are used. In some forms of disease, however, especially in Bright's disease, cholera, and certain other pathological conditions, in which the functions of the urinary organs are to any serious extent interfered with,

the amount of urea is found to increase considerably, and may frequently be met with in a sufficiently large quantity to be weighed.

599. The detection and estimation of urea in the blood may be conducted in the following manner. A known weight of serum is first evaporated to dryness on a water bath, at a *very gentle* heat, a precaution necessary to be observed, since a temperature of 212°, long continued, such as is required in this analysis, would probably cause the decomposition of some portion of the urea. The dry residue is reduced to fine powder in a mortar, and treated with distilled water, heated to about 200°, the quantity of which may be about double the volume of the serum employed in the experiment. The mixture is allowed to digest for about half an hour, at 200°, after which it may be filtered from the insoluble residue of albumen, which latter must be washed while on the filter, with a little more warm water. The filtered aqueous solution is now evaporated to dryness, and the residue digested with a little absolute alcohol, at a very gentle heat, which may be continued for about half an hour; a little fresh alcohol being added occasionally, to replace that lost by evaporation. The mixture is then filtered; the clear alcoholic solution is evaporated to dryness, and the residue treated with a little lukewarm distilled water, which will then contain merely the urea, together with a small quantity of extractive matter.

600. The aqueous solution thus obtained, is evaporated at a very gentle heat, to the consistence of a syrup, and then mixed with a few drops of pure and colourless nitric acid (16, 182), the mixture being kept cool by immersing the glass containing it in a little cold water, or, still better, in a freezing mixture composed of equal weights of crystallized nitrate of ammonia and water. If urea is present, delicate crystalline plates of nitrate of urea ($C_2H_4N_2O_2$, HO,NO_5) will gradually appear (Fig. 2, page 5), which, if in sufficient quantity, may be dried by gentle pressure between folds of filtering paper, and weighed. From the weight thus obtained, that of the urea in the quantity of serum employed, may be calculated as follows:—

$$\underbrace{\left\{\begin{array}{c}\text{Atomic wt.}\\ \text{of nitrate}\\ \text{of urea.}\end{array}\right\}}_{123} : \underbrace{\left\{\begin{array}{c}\text{Atomic}\\ \text{wt. of}\\ \text{urea.}\end{array}\right\}}_{60} :: \underbrace{\left\{\begin{array}{c}\text{Wt. of nitrate}\\ \text{obtained.}\end{array}\right\}}_{a} : \underbrace{\left\{\begin{array}{c}\text{Wt. of urea in}\\ \text{quantity of}\\ \text{serum employed.}\end{array}\right\}}_{x}$$

601. If no appearance of crystallization can be detected with the naked eye, a drop of the acid liquid, cooled by means of a freezing mixture, is to be examined under the microscope, by which means very small traces of urea may be detected (181).

602. The quantitative determination of the other constituents may be effected with a fresh portion of the blood, in the same manner as in the healthy fluid (503, &c).

SECTION VIII.

Blood containing an excess or deficiency of inorganic saline matter.

603. The average proportion of inorganic saline matter in healthy blood appears to be about seven parts in 1000. In scurvy, and some other pathological conditions, their amount has been found to increase, and has been known to amount to as much as eleven parts in 1000. In some other diseases, on the contrary, the amount falls below the healthy average.

The proportion of fixed saline matter in any specimen of morbid blood, may be determined as in the case of the healthy fluid—viz., by evaporating to dryness a known weight, and incinerating the residue until the ash becomes nearly colourless. The weight of the ash thus obtained, represents the amount of salts in the quantity of blood employed.

604. The presence of uric acid (urate of soda) in the blood of gouty patients, may be shown by evaporating a little of the fluid to dryness on a water-bath, and adding a slight excess of dilute hydrochloric or acetic acid to a strong aqueous solution of the extract. After standing a day or two, minute crystals of uric acid, similar to those formed in the urine, are gradually deposited, and may be identified under the microscope (186, 194), or by their behaviour when treated with nitric acid and ammonia (23).

Class II.—*Morbid blood containing some abnormal ingredient.*

SECTION IX.

Blood containing Sugar ($C_{12}H_{14}O_{14}$).

605. The blood of patients suffering from diabetes appears most commonly to contain a very sensible amount of sugar. This may usually be detected in the following manner.

606. The portion of serum intended for examination is first evaporated to dryness, either in vacuo over sulphuric acid (Prac. Chem. 646), or at a very gentle heat on a water bath. The dry residue is then reduced to tolerably fine powder, and treated with a small quantity of boiling water, which will have the effect of coagulating the albumen, and dissolving out the sugar, together with the extractive matters and soluble salts. The mixture is then filtered, and the clear liquid examined for sugar, by means of Trommer's test, which may be thus applied.

607. The liquid is treated with a drop or two of a solution of sulphate of copper, and then supersaturated with potash (123), the excess of which will probably, if sugar is present, redissolve the blue precipitate of hydrated oxide of copper at first thrown down. The mixture may now be gently boiled for a few minutes, when, if sugar is present, an orange brown or ochre-coloured precipitate of suboxide of copper will be thrown down; while, if no sugar is contained in the mixture, the precipitate will be nearly black (124).

608. It is always more satisfactory when practicable, even when Trommer's test affords tolerably decided indication of sugar, to confirm the result by applying also the fermentation test (127), and examining under the microscope for the torula (132); since certain other organic matters besides sugar give rise to the formation of the suboxide.

609. When, after having proved the presence of sugar in the blood, it is required to determine its amount, the following method of insulating it is perhaps the best, though the results must not be regarded as by any means exact,

but merely as an approximation to the truth. The fermentation process (336) cannot be here applied, since traces of carbonic acid may be evolved by some of the other constituents of the blood, when no sugar is present.

610. A known weight of serum is evaporated to dryness, either in vacuo over sulphuric acid (Prac. Chem. 646), or at a very gentle heat on a water bath. The dry residue is then finely comminuted, and treated with boiling water, in which it may be allowed to digest for three or four hours, in order to ensure the solution of the whole of the soluble matter. The aqueous solution is separated from the albumen by filtration, and evaporated to dryness as before. The dry residue is now digested with alcohol, which leaves undissolved portions of the saline and extractive matters. The alcoholic solution is again evaporated to dryness, and the dry residue treated with ether, which dissolves out the fat, leaving undissolved the sugar, mixed with a little alcohol extractive and chloride of sodium. This residue is once more dissolved in alcohol, and the alcoholic solution, on being allowed to evaporate spontaneously, will gradually deposit the sugar, mixed with a little chloride of sodium, in the form of small hard crystals. These are to be washed with a very small quantity of cold water, and pressed between folds of filtering paper, in order to remove most of the uncrystallizable matter. The mixed crystals of sugar and salt are then dried on a water bath, and weighed. By careful incineration, the sugar may then be burnt off, leaving the incombustible saline matter; the weight of which, when deducted from that of the dry mixture previous to incineration, will represent the proportion of sugar in the quantity of serum used.

611. The quantitative determination of the other constituents of blood containing sugar may be effected in the same manner as in the case of healthy blood, the weight of the sugar being deducted from the extractive matter (503, &c.)

SECTION X.

Blood containing Biliary Matter.

612. In jaundice, and some other affections in which the functions of the liver are interfered with, an accumulation of biliary matter is found to take place in the blood, giving

the serum a more or less decided saffron or orange brown colour, which is due to the peculiar colouring matter of the bile, called biliphœin.

613. The presence of bile in the blood may be detected by adding to a little of the clear serum, a few drops of nitric acid, which will throw down the albumen; the precipitate having, if biliary matter (biliphœin) is present, a decided greenish tint, while in healthy serum it would be white, or very nearly so.

614. If so small a quantity of bile is present as to fail in producing a perceptibly green colour with nitric acid, a little of the suspected serum may be first concentrated by evaporation at a temperature not exceeding 120° or 130°, and then exhausted with alcohol or water, and the solution tested in the manner already described in the case of urine (149—152).

615. We have at present no means of estimating the quantity of biliary matter contained in blood, though the depth of colour of the serum furnishes some indication of the relative amount present. The quantitative determination of the other constituents of the blood may be made in the same manner as in the analysis of the healthy fluid (503, &c.)

SECTION XI.

Blood containing Pus.

616. The existence of pus in morbid blood is probably by no means a rare occurrence, especially in diseases which are attended with suppuration. Its detection, however, is far from easy, since we possess no characteristic chemical test by which it may be distinguished from the ordinary constituents of the blood; and in microscopic appearance, the pus granules very closely resemble the colourless corpuscles which are always present in the blood (464). The pus granules are in general somewhat larger than the white corpuscles of the blood, and when treated with dilute acetic acid, develop internal nuclei, which are usually from three to five in number, and more distinct than those in the white corpuscles of the blood. The pus granules, when present in blood, appear to have a tendency to adhere together in groups of five or six; while the colourless corpuscles of the blood always float detached from each other.

617. According to Heller, the granules of pus, when mixed with blood, subside much more slowly than the blood corpuscles; so that when present, they may always be found in the uppermost layer of the coagulum. He recommends a thin slice to be taken from the upper surface of the latter, which after being mixed with a little distilled water, should be filtered through muslin, in order to separate the fibrin. The blood corpuscles are for the most part dissolved by the action of the water (458); and after allowing the filtered liquid to stand a short time in a tall glass, the pus granules will be found at the bottom of the liquid, and may be detected under the microscope.

618. The action of ammonia upon pus has been proposed by Donné as a test for its presence in the blood. When blood, free from pus, is mixed with ammonia, it becomes clear; while if pus is present in any considerable quantity, the liquid becomes more or less gelatinous. If the amount of pus present is small, stringy flocculi only are formed, which subside to the bottom of the liquid.

SECTION XII.

Blood containing Animalcules.

619. Instances have occasionally been observed, in which minute thread-like animalcules have been present in considerable numbers in the blood. Those described by Dr. Goodfellow, which he detected in the blood of a patient suffering from fever, measured from $\frac{1}{5000}$th to $\frac{1}{3000}$th of an inch in length, and from $\frac{1}{40000}$th to $\frac{1}{20000}$th of an inch in diameter. The only method of detecting such entozoa in the blood, is to examine it carefully under the microscope, with as high a magnifying power as the observer has at his command.

PART IV.

MILK, MUCUS, PUS, BONE, &c.

CHAPTER I.

MILK.

SECTION I.

General characters of Milk.

620. Milk, as is well known, is a watery liquid, having in solution a certain amount of casein, sugar of milk, or lactine, and extractive matter, together with several inorganic salts, and holding in suspension myriads of extremely minute globules of fatty matter, plainly visible through the microscope, which give the fluid its peculiar white and opaque appearance. It has a pleasant and rather sweetish taste, and a slight agreeable smell, especially while warm. The specific gravity of milk varies considerably; that of woman being sometimes as low as 1020 (the average being 1032), while that of the sheep is as high as 1041.

621. Fresh milk is almost invariably slightly alkaline to test paper, but on exposure to the air, especially in warm weather, it rapidly becomes acid, owing to the conversion of the sugar of milk into lactic acid ($HO,C_6H_5O_5$), under the influence of the casein, which acts as a ferment (630). If the milk has been long retained in the mammary glands, this change occasionally takes place before being drawn; and in some morbid conditions also, the milk is found to have an acid reaction even when freshly drawn.

622. When allowed to stand for a few hours, the fatty globules, which have a somewhat lower specific gravity than the fluid portion of the milk, gradually rise to the surface, carrying with them a portion of the caseous matter,

forming a layer of cream, which is more or less thick and copious in proportion to the richness of the milk.

623. If a little acetic or lactic acid, rennet, or even sour milk, be added to hot milk, the casein of the latter is precipitated in the coagulated form; and the same effect is produced by warming milk or cream which has been allowed to turn sour; the sourness being due to the lactic acid, into which the sugar of milk has been converted. The solid and liquid portions into which the milk is thus divided, are commonly called curds and whey.

624. Before describing the mode of analyzing milk, I will briefly notice the several constituents which we find contained in it—viz., casein, sugar of milk, fat globules, and saline matter.

SECTION II.

Casein.

625. Casein is a modification of protein* (472) peculiar to the milk, and constitutes the chief source of nourishment to the young animal; for which purpose it is admirably adapted, from the readiness with which it appears capable of being converted into the other modifications of protein—viz., fibrin and albumen.

626. It may be obtained in a state of tolerable purity by evaporating a quantity of milk to dryness on a water-bath, and reducing the dry residue to powder in a mortar. This is then boiled in successive portions of ether, in order to dissolve out the fat. The residue which remains insoluble in the ether is then dried, and digested in water, which will dissolve the casein and other soluble matters of the milk. On adding alcohol to the aqueous solution, the casein is thrown down in the form of a white curdy precipitate, which may be purified by again dissolving it in water, and once more precipitating it by means of alcohol.

627. It is most probable that pure casein is insoluble, or very sparingly soluble, in water, and owes its solubility in milk to the small quantity of alkali which is present. When dry, it closely resembles fibrin and albumen in appearance (479), and its behaviour with reagents is in

* See note to 471.

most cases very similar; it differs from the latter chiefly in not coagulating when heated; and it is precipitated by acetic, and nearly all the acids, but redissolves in a considerable excess of most of them. The ferrocyanide and ferridcyanide of potassium also cause precipitates in solutions of casein.

SECTION III.

Sugar of milk, or Lactine ($C_{24}H_{24}O_{24}$).

628. The sugar contained in milk, may be prepared in the following manner:—The curd, including the greater part of the casein and fat globules, is first separated by the addition of a few drops of acid to hot milk, and the remaining traces of those substances are then removed by mixing a little well-beaten white of egg with the whey when cold, and afterwards boiling the mixture. The whey, thus clarified by the coagulating albumen of the egg, is filtered from the precipitate by passing it through muslin or calico; and the clear liquid may then be evaporated to about one-fourth, or one-fifth its bulk, and set aside in a cool place for a few days. The sugar will gradually separate from the liquid, in the form of minute hard crystals, which adhere to the surface of the containing vessel. These may be purified by dissolving them again in water, boiling the solution with animal charcoal, and recrystallizing.

629. This variety of sugar is less sweet than that obtained either from the cane or the grape (114); it is also harder, and less soluble in water, requiring as much as five or six times its weight of cold, and two and a half times its weight of hot water to dissolve it. When mixed with a little hydrochloric or sulphuric acid, sugar of milk gradually becomes converted into grape sugar ($C_{12}H_{14}O_{14}$), and this change takes place more rapidly if the solution is boiled.

630. Under the influence of the caseous matter of the milk, this form of sugar gradually passes into lactic acid ($HO,C_6H_5O_5$), a change easily accounted for, since the formula of the sugar is a multiple of that of the acid, one equivalent of the former being broken up into four of the latter.

$$C_{24}H_{24}O_{24}=4\ (HO,C_6H_5O_5).$$

SECTION IV.

Fat Globules.

631. The minute globules which are held suspended in milk, and to which the opacity and whiteness of the fluid are due, consist mainly of oily fat, which appears to be surrounded by a thin covering of insoluble matter, differing in its properties from fat, and probably composed of one of the modifications of protein.

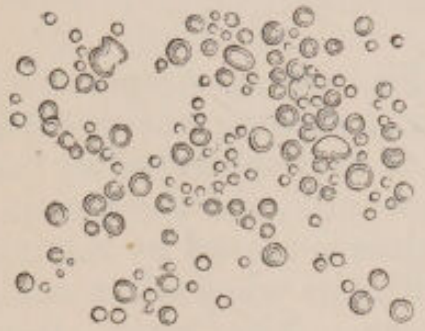

Fig. 65. Milk globules.

632. The size of the globules in healthy milk varies from a mere point, to about $\frac{1}{2000}$th of an inch in diameter, the average size being rather more than $\frac{1}{4000}$th (Fig. 65).

633. In the milk which is secreted during the first few days of lactation, called the colostrum, and which is always much richer in quality than ordinary milk, we find, in addition to the common milk globules, numerous granular corpuscles of a pale yellowish colour, and considerably larger than the others, their diameter varying from $\frac{1}{2000}$th to $\frac{1}{800}$th of an inch (Fig. 66). Similar corpuscles are also occasionally present in milk secreted during disease. They appear to be almost peculiar to human milk, being rarely met with in that of the cow and other animals.

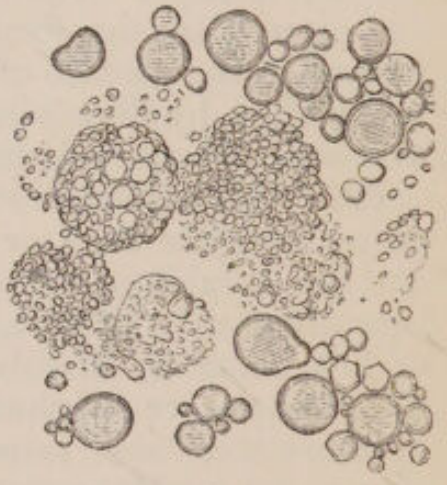

Fig. 66. Colostrum corpuscles.

634. The fatty matter of milk consists for the most part of a solid fat called margarine ($C_{74}H_{74}O_{12}$), mixed with a liquid fat or oil called oleine ($C_{78}H_{75}O_{13}$), together with small quantities of butyrine and other fats. The proportion in which these several fats are found mixed in milk, varies considerably, being influenced by the health and food of the individual, the season of the year, and other circum-

stances. A specimen of the fat contained in cow's milk, analyzed by Bromeis, contained—

Margarine	68
Elaine	30
Butyric, caproic, and capric acids	2
	100

SECTION V.

Saline Matters.

635. It is probable that the following salts are present in milk, though an analysis of the ash will not, of course, detect the organic and volatile compounds included in the list, since they are either decomposed or volatilized during the process of incineration:—the chlorides of potassium and sodium; the phosphates of potash, soda, lime, and magnesia, with traces of phosphate of the peroxide of iron; and the lactates of potash, soda, lime, magnesia, and probably of ammonia.

636. According to Haidlen, the ash obtained by incinerating 1000 parts of cow's milk, consisted, in two instances, of the following substances:—

	I.	II.
Phosphate of lime	2.31	3.44
Phosphate of magnesia	0.42	0.64
Phosphate of peroxide of iron	0.07	0.07
Chloride of potassium	1.44	1.83
Chloride of sodium	0.24	0.34
Soda	0.42	0.45
	4.90	6.77

637. The presence of these several salts may be proved by applying to a solution of the ash in water and hydrochloric acid, the tests mentioned in the chapters on the urine and the blood (41, 490, &c.)

SECTION VI.

Composition of Human Milk.

638. In healthy human milk, the several constituents which I have now briefly described, are not always present in the same relative proportions; various circumstances, as those of age, temperament, and food of the mother, as well as the period of lactation, causing considerable variations in the composition of the secretion. The following examples will serve to show to what extent these variations usually occur.

Analysis I. (Simon.)

Showing the mean of fourteen analyses made at different periods, with the milk of the same woman.

Water	883.6
Solid constituents	116.4
Butter	25.3
Casein	34.3
Sugar of milk and extractive matters	48.2
Fixed salts	2.3

Analyses II., III. & IV. (Clemm.)

	The fourth day after delivery.	The ninth day after delivery.	The twelfth day after delivery.
Water	879.848	885.818	905.809
Solid constituents	120.152	114.182	94.191
Butter	42.968	35.316	33.454
Casein	35.333	36.912	29.111
Sugar of milk and extractive matters	41.135	42.979	31.537
Salts	2.095	1.691	1.939

Analyses V. & VI. (L'Heretier.)

Water	867.8	870.6
Solid constituents	132.2	129.4
Butter	42.5	52.0
Casein	11.7	9.5
Sugar of milk	74.0	63.4
Salts	4.0	4.5

Analysis VII. (*Chevallier and Henri.*)

Water	879.8
Solid constituents	120.2
Butter	35.5
Casein	15.2
Sugar of milk	65.0
Salts	4.5

SECTION VII.

Composition of the Milk of other animals.

639. The proportion of the several constituents is found to differ considerably in the milk of different animals. The subjoined table, showing the composition of the milk of a few of the more important domestic animals, from the analyses of Chevallier and Henri, will serve to illustrate this:—

	Cow.	Ass.	Goat.	Ewe.
Casein	4.48	1.82	4.08	4.50
Butter	3.13	0.11	3.32	4.20
Sugar of milk	4.77	6.08	5.28	5.00
Saline matter	0.60	0.34	0.52	0.68
Water	87.02	91.65	86.80	85.62
	100.00	100.00	100.00	100.00

CHAPTER II.

QUANTITATIVE ANALYSIS OF MILK.

640. Two portions of milk, one weighing about 100 grains, and the other about 400 grains, are to be accurately weighed, the first in a platinum crucible or capsule, and the second in a porcelain capsule; both the vessels having been previously weighed or counterpoised. The first portion, of 100 grains, we will call A, and the second, of 400 grains, we will call B.

641. *Treatment of the portion A.*—This portion, after being weighed, is to be evaporated to dryness on a water bath, or, still better, on a chloride of calcium bath, heated to about 220°, until, on being weighed at intervals of half an hour or an hour, it ceases to lose any further weight. The weight of the dry residue will then represent the amount of SOLID MATTER contained in the quantity of milk used, while the loss of weight during evaporation shows the amount of WATER.

642. In these and the other determinations, the proportion present in 1000 parts of the milk, is calculated in the following manner:

{Wt. of milk used in the experiment.} : {Wt. of each constituent obtained.} :: 1000 : {Proportion of that constituent in 1000 parts of the milk.}

643. The weight of the dry residue having been noted, the crucible, with its contents, is to be placed over a lamp, and kept at a red heat until the whole of the charcoal is burnt away, and the ash becomes white or nearly so. The weight of the ash thus obtained, will represent the amount of INORGANIC SALINE MATTER in the quantity of milk evaporated; from which the proportion in 1000 parts may be calculated as before (642).

644. *Treatment of the portion B.*—This portion, after being weighed, is to be mixed with about one-fourth its weight of finely pounded hydrated sulphate of lime (CaO, SO_3+2Aq), or unburnt gypsum, with which it is to be well stirred for a short time, and then raised to a temperature of 212°; by which means the whole of the casein will become coagulated, and insoluble in water. The mixture is now to be evaporated to dryness on a water bath, being occasionally stirred, in order that the solid residue of the milk may be pretty uniformly mixed with the sulphate of lime.

645. The mass, when dry, is then easily reduced to powder; after which it is to be digested with successive small quantities of ether, which will dissolve out the whole of the fatty matter. The ethereal solution is now evaporated to dryness on a water bath, and the residue weighed; its weight representing the amount of FAT in the quantity of milk operated on; from which the proportion present in 1000 parts of milk may be calculated as before (642).

646. The portion of the residue which proved insoluble in ether (645) is now to be treated with hot alcohol, as long as anything dissolves. In this way, the whole of the sugar, together with a little saline matter and alcohol extractive, is dissolved. The alcoholic solution is to be evaporated to dryness on a water, or chloride of calcium bath, and the dry residue, having been accurately weighed, is incinerated; the difference between the weight before and after incineration, will then represent the quantity of SUGAR, with a little alcohol extractive matter, in the portion of milk employed. The proportion contained in 1000 parts is then calculated as in the former cases (642).

647. The remaining portion of the dry residue, which resisted the action of the alcohol (646), is to be dried on a water, or chloride-of-calcium bath, weighed, incinerated, and the weight of the ash ascertained. The loss of weight during incineration will represent the amount of CASEIN, with a little water extractive matter, in the quantity of milk used, from which the proportion in 1000 parts may be determined as before (642).

648. The proportion of CASEIN may also be estimated by adding together the amount of water, fat, sugar, and saline matter, already ascertained as being present in 1000 parts of the milk, and deducting the sum of them from 1000. The experimental determination is, however, to be preferred.

CHAPTER III.

MILK DURING DISEASE.

649. The milk which is secreted during disease is usually more or less modified in its composition; even slight derangements of the system, and any great mental anxiety or sudden emotion of fear, &c., not unfrequently have the effect of disturbing, in a remarkable manner, the natural character of the secretion. The exact nature of these changes is very imperfectly understood. They are probably sometimes merely variations in the relative proportions of the several constituents of the healthy fluid; at others, and perhaps more frequently, certain abnormal matters are formed.

650. With the assistance of the microscope, we are not unfrequently able, with great facility, to detect the presence of certain morbid products which are not found in the healthy secretion. The peculiar form of milk called the colostrum, which is secreted during the first few days of lactation, has been already mentioned as differing very considerably in microscopic appearance from healthy milk, and as containing numerous granular corpuscles, much larger than the ordinary milk globules (633). The corpuscles of the colostrum also show a tendency to adhere to each other, while the globules of the healthy fluid usually float freely about. It occasionally happens that the milk, instead of changing, in the course of a few days, to its more natural condition, continues for a length of time to possess the characters peculiar to colostrum; and has even been observed to change back again to this condition, after being secreted for a time in a healthy state. The presence of the colostrum corpuscles (Fig. 66), and the slightly viscid appearance also characteristic of this condition, may at once be detected under the microscope.

651. The presence of pus, which during the formation of a mammary abscess often finds its way into the milk, may also be detected under the microscope, by the occurrence of the peculiar pus granules (Fig. 67). Blood corpuscles, too (451), are also found, though more rarely than those of pus, owing, in most cases, to the rupture of some of the minute blood-vessels with which the mammary gland is permeated (Fig. 68).

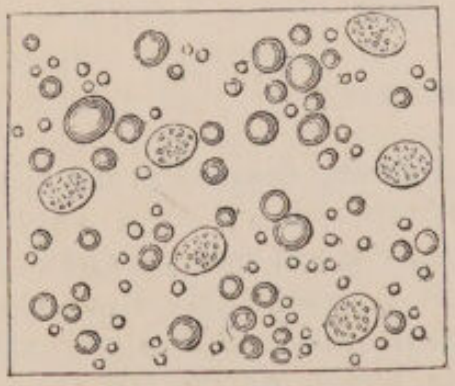

Fig. 67. Pus in milk.

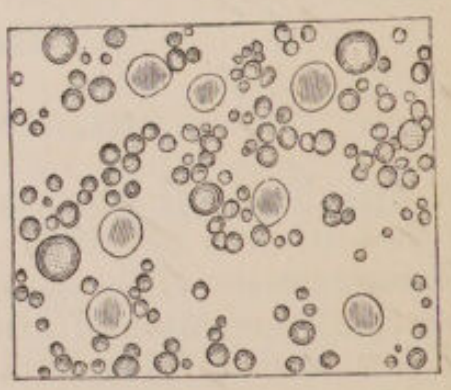

Fig. 68. Blood in milk

652. In addition to the strictly morbid products, other substances, especially certain salts, which have been taken into the system either in the food or as medicine, appear

occasionally to find their way into the milk, where they may sometimes be detected by the proper tests.

Analysis of the colostrum of a woman, together with that of the healthy milk of the same individual. (*Simon.*)

	Colostrum.	Healthy Milk.
Water	828.0	887.6
Solid constituents	172.0	112.4
Fat	50.0	25.3
Casein	40.0	34.3
Sugar of milk	70.0	48.2
Saline matter	3.1	2.3

CHAPTER IV.

THE ADULTERATIONS OF MILK.

653. It is well known that much of the milk which is supplied in large towns is almost constantly more or less adulterated, and although the substances employed for the purpose are in most cases comparatively innoxious, it is much to be wished that some simple and efficient test of its genuineness and purity could be devised, capable of being applied by those who are unaccustomed to experiment.

654. The substances most commonly used for the purpose of adulteration appear to be, water, flour, starch, and finely-pounded chalk; and besides these, the macerated brains of sheep and other animals are said to be sometimes introduced. All these, with the exception of the first, may be easily detected.

655. On examining a little of the milk under the microscope, the peculiar granules of starch and flour may be readily seen (Fig. 69 *a*), larger and more oval than the milk

Fig. 69. Starch granules.

globules, if either of those substances is present; and when examined with polarized light, each granule will be found to exhibit a dark cross, as shown at *b*, in the figure. Should any doubt exist as to their real nature, the addition of a drop or two of a solution of iodine will impart to the farina granules a dark purple colour.

656. The microscope will also serve to show the presence of macerated brain, which may be recognised by the occurrence of fragments of nerve and other organized structures, not found in pure milk.

657. The presence of chalk may be still more easily discovered, since, owing to its specific weight, it soon subsides to the bottom of the liquid, where it may at once be recognised by its effervescing on the addition of a little dilute hydrochloric acid.

658. We have no chemical means of ascertaining whether water has been fraudulently added to milk, the only effect being to dilute it, and render it of poorer quality. A knowledge of the specific gravity cannot here be made available, since the abstraction of a portion of the cream, which has a lower specific gravity than milk, may be made to neutralize the effect produced by the addition of water; the tendency of the removal of the cream being to raise the specific gravity of the fluid, and that of the addition of water, to lower it. A specimen of milk, therefore, which has been impoverished by the abstraction of its cream, and still further weakened by the addition of water, may be made to possess the same specific gravity as it had when taken pure from the udder.

659. It occasionally happens that the milk exposed for sale is the produce of an unhealthy animal. Such milk

has usually some peculiarity of taste or smell, and also a slightly viscid and unnatural appearance; on being examined under the microscope, too, it will probably be found to contain pus or mucus corpuscles, or to present other appearances differing from those of the healthy secretion.

CHAPTER V.

MUCUS.

SECTION I.

General Characters of Mucus.

660. Healthy mucus, which is secreted by the mucous membrane with which the internal surfaces of the several parts of the body are covered, is a semi-fluid viscid substance, the general appearance of which is well known. It is sometimes so thin and limpid as almost to resemble water in appearance; while at others, and more commonly, it is tough, and extremely tenacious, becoming stringy when attempted to be drawn out. When thin and watery, it is nearly transparent and colourless; the more viscid forms, however, being turbid or opaque, and usually of a pale yellowish or greyish colour. It is usually alkaline to test paper, insoluble in water, and somewhat heavier than that fluid; so that when placed in water it gradually sinks to the bottom, unless it is buoyed up by entangled air-bubbles. The mucus obtained from the several parts of the body differs considerably in appearance, and probably also in chemical composition. When dry, it is hard and friable, resembling horn in appearance; the dry mass, on being digested in water, gradually swells up, and partially reassumes its former appearance.

661. When mucus is examined under the microscope, with a power of about 200 diameters, it is found to contain

numerous round or oval granular corpuscles, together with epithelial scales (Fig. 5), entangled in a more or less viscid fluid, to which latter the peculiar tenacious character of mucus appears to be due. Mucus, therefore, consists of two distinct portions; the solid corpuscles with epithelial scales, and the fluid with which they are surrounded. Under favourable circumstances, and with a high magnifying power, the fluid portion appears to be filled with extremely minute molecular particles, the nature of which is not clearly understood.

662. The size of the mucus corpuscles varies considerably, the average diameter being about $\frac{1}{2000}$th of an inch. Their surfaces are granular (Fig. 70, *a*), similar to those of pus (678); and when treated with dilute acetic acid, the exterior covering loses its granular appearance, and becomes transparent, rendering visible from one to five internal nuclei (Fig. 70, *b*). The same effect is produced by dilute oxalic and tartaric acids; but the dilute mineral acids cause little or no change.

663. Mucus appears to contain in its composition the following substances:—mucus corpuscles, epithelial scales, mucin, traces of extractive matters and fat, sometimes a small trace of albumen, and saline matters; which latter consist of alkaline chlorides and lactates, phosphate of lime, and traces of carbonate of soda. The *mucin*, to which the peculiar tenacious character of mucus appears to be due, is insoluble in pure water, and is probably held in solution in the fluid portion of the mucus, by the small excess of alkali usually present; it separates in the form of a white coagulum when mucus is treated with water, and still more completely when neutralized with dilute acetic acid. The minute traces of fat found in mucus probably exist in the corpuscles, though the exact chemical nature of these is by no means clearly ascertained.

SECTION II.

Quantitative Analysis of Mucus.

664. The quantitative determination of the principal constituents of mucus may be made in the following man-

ner. The mucus intended for analysis is first divided into two portions, A & B; the first, A, being about one quarter, and the second, B, about three quarters, of the whole. Both portions are to be weighed in counterpoised capsules, that containing A being of platinum, and evaporated to dryness on a chloride-of-calcium bath, at a temperature of about 220°.

665. *Treatment of the portion A.*—This portion, after being dried until it ceases to lose weight, is to be accurately weighed. The weight of the dry residue gives the amount of SOLID MATTER in the quantity of mucus evaporated, while the loss represents the amount of WATER.

666. The proportion of these and the other ingredients, contained in 1000 parts of the mucus, may in each case be estimated by the following calculation:—

Weight of mucus before evaporation.	:	Wt. of each constituent contained in the quantity of mucus employed.	:: 1000 :	Proportion of that constituent contained in 1000 parts of mucus.

667. The dry residue is then to be incinerated at a low red heat, until the ash becomes white, or nearly so. The weight of the ash will then represent the amount of SALINE MATTER in the quantity of mucus used, from which the proportion present in 1000 parts may be calculated as before (666).

668 *Treatment of the portion B.*—The dry residue left after evaporation (664), is to be removed from the capsule, and reduced to fine powder in a mortar. It is then boiled with successive small portions of ether, which will dissolve out the fat. The etherial solution is evaporated to dryness on a water bath, when the weight of the residue will indicate the amount of FAT in the quantity of mucus employed, from which the proportion in 1000 parts may be estimated as before (666).

669. The residue which proved insoluble in the ether (668) is to be boiled with a little alcohol, after which the alcoholic solution is to be evaporated to dryness, and the dry residue weighed. This is then incinerated, and the weight of the ash, deducted from that of the dry extract, will give the amount of ALCOHOL EXTRACTIVE, with the lactic acid of the lactates, in the quantity of mucus used; which may be corrected, as before, for 1000 parts (666).

670. The portion of the residue which proved insoluble in the alcohol (669), is to be dried and weighed; the weight indicating the amount of MUCIN, together with cellular matter, and probably traces of albumen, in the quantity of mucus employed; from which the proportion present in 1000 parts of mucus may be calculated, as in the former cases (666).

671. According to Nasse, the composition of fresh pulmonary mucus is as follows:—

Water	955.520
Solid constituents	44.480
Mucin, with a little albumen	23.754
Water extract	8.006
Alcohol extract	1.810
Fat	2.887
Chloride of sodium	5.825
Sulphate of soda	0.400
Carbonate of soda	0.198
Phosphate of soda	0.080
Phosphate of potash, with traces of iron	0.974
Carbonate of potash	0.291
Silica, and sulphate of potash	0.255

SECTION III.

Morbid Mucus.

672. The characters of mucus secreted during disease are usually more or less different from those of the normal secretion, and an admixture of foreign matters frequently alters its appearance considerably. Pus, for instance, when mixed with it, diminishes its tenacity, owing to the mucin being present in smaller proportion (663); and when the liquid portion of mucus containing an admixture of pus, is tested for albumen (254, 677), a considerable amount of that substance may usually be detected; since the *liquor puris*, or liquid portion of pus, contains a comparatively large quantity of albumen, but no mucin. Our means of detecting the presence of minute traces of pus in mucus are very imperfect; the decided presence of albumen in the

purulent secretion is, indeed, almost the only test, since the microscopic characters of the corpuscles appear to be identical in both (249).

673. The morbid mucus expectorated in pulmonary disease frequently contains, besides pus, red blood corpuscles, minute globules of fat, fragments of tuberculous matter, and other abnormal substances, most of which may generally be detected without difficulty under the microscope. The indications afforded by a careful microscopic examination of such expectorations indeed, may often lead to results in diagnosis, of great importance to the practical physician.

CHAPTER VI.

PUS.

SECTION I.

General Characters of Pus.

674. Pus is the peculiar semi-fluid matter which is formed in abscesses, and in other kinds of wounds. In common language, a considerable variety of substances, more or less resembling each other in appearance, though differing in many respects, are included under the name of pus; and hence it has been found necessary to distinguish the normal secretion by the name of *true*, or *genuine pus;* the other substances being called *spurious*, or *false pus*.

675. Normal pus is a thick creamy-looking fluid, perfectly opaque, and usually of a pale yellow or greenish colour. It possesses little or no tenacity, and may consequently be poured in separate drops, in which respect it differs essentially from mucus, which, in colour and general appearance, it often much resembles. Its specific gravity is usually about 1030 or 1033, so that it sinks in water;

and if shaken up with that fluid, mixes uniformly with it. The mixture, after standing a short time, gradually deposits a sediment, consisting of the pus corpuscles (678). It is most commonly neutral to test paper, but is also occasionally met with slightly acid and alkaline.

676. Like mucus, pus consists of a clear fluid portion or serum, in which float innumerable minute granular corpuscles, which latter appear to be almost precisely the same as those contained in mucus, and when examined under the microscope, exhibit the same granular appearance. The liquid portion of pus, or *liquor puris*, however, differs essentially from the fluid portion of mucus, and contains the following substances in solution, which, it will be seen, are nearly the same as those held in solution in the serum of the blood (573)—viz., albumen, together with a peculiar compound called pyin, or tritoxide of protein, which is soluble in water, and precipitated by acetic acid, fat, extractive matters, and inorganic salts. These latter consist, for the most part, of chloride of sodium, with small quantities of phosphate, sulphate, and carbonate of soda; the chlorides of potassium and calcium; phosphates and carbonates of lime and magnesia; and traces of peroxide of iron.

677. The presence of these matters in the *liquor puris* may be shown by placing some pus in a tall narrow glass, and allowing it to stand, in order to give the corpuscles time to subside; after which a little of the clear liquid may be drawn off with a pipette. On boiling a few drops of this in a test tube, the albumen becomes coagulated, and separates from the liquid; after which the pyin may be thrown down in the form of a white flocculent precipitate, by adding a little acetic acid. The liquid may then, if necessary, be tested for the several inorganic salts above enumerated (676, 490).

678. The pus corpuscles, though quite invisible to the naked eye, may be distinguished under the microscope with a magnifying power of from fifty to one hundred diameters; a considerably higher power, however, is required for exhibiting their peculiar granular structure (Fig. 70, *a*). The size of these corpuscles varies considerably, being commonly about $\frac{1}{2000}$th of an inch in diameter. They are nearly spherical; and have a very pale yellowish colour, which is scarcely perceptible, unless several of them

are aggregated together. Being slightly heavier than the liquor puris with which they are surrounded, they gradually subside to the bottom, leaving the fluid portion nearly clear. Minute globules of fat may usually be detected, mixed with the corpuscles.

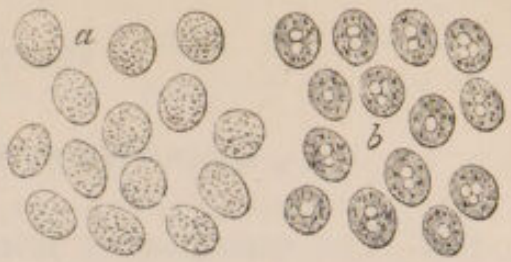

Fig. 70. Pus corpuscles, magnified 400 diameters.

679. The pus corpuscles, when treated with liquids of different densities, exhibit the phenomena of endosmosis and exosmosis, somewhat similar to those already described as taking place in the corpuscles of the blood (456); increasing in size when the external liquid, such as pure water, is of lower density, and collapsing when it is of higher density, than the fluid contained in them. When treated with dilute acetic acid, the external covering becomes transparent, and exhibits one or more internal nuclei (Fig. 70, *b*).

680. When mixed with a solution of ammonia, pus loses its fluidity, and assumes a jelly-like appearance, which is highly characteristic. A somewhat similar effect is produced also by the alkaline carbonates, and certain other salts.

681. Although the general appearance and characters of pus are usually sufficiently marked to enable us to identify it, it is always advisable, in cases where any doubt exists, to submit it to microscopic examination; since occasionally we meet with fluids containing a large quantity of epithelium and other products, which, in appearance, closely resemble pus, though differing entirely in composition from that substance, and containing no trace of the characteristic pus corpuscles (678). The form of these corpuscles is found to vary considerably under certain pathological conditions; but there may generally be traced sufficient resemblance to the normal corpuscles, to enable us to distinguish them from other matters. The modes of distinguishing between pus and mucus, have been already noticed in paragraphs 248, &c.

SECTION II.

Quantitative Analysis of Pus.

682. The quantitative analysis of pus may be made in the following manner:—Two portions of the fluid are to be weighed out; the first, A, in a small counterpoised flask; and the second, B, in a counterpoised or weighed evaporating dish.

683. *Treatment of the portion A.*—The portion A, after being weighed in the flask, is to be boiled with successive small quantities of strong or absolute alcohol, which must be separated while hot, either by filtration or decantation, from the insoluble portion. The alcoholic solution is then set aside to cool, and allowed to stand a few hours, in order that the fat may, for the most part, crystallize out. The cold alcoholic liquid is then poured off, and the solid matter dried and weighed; when the weight thus obtained will represent the amount of FAT in the quantity of pus employed in the experiment.

684. The cold alcoholic liquid (683) is now to be evaporated to dryness in a counterpoised platinum capsule, and the dry residue, after being weighed, is incinerated. The weight of the ash is then ascertained, when the difference between the weight before and after incineration, will represent the quantity of EXTRACTIVE MATTER (together with traces of fat which had not separated from the cold alcohol), in the portion of pus employed.

685. The residue which proved insoluble in the boiling alcohol (683), is to be dried on a water bath, and then boiled with a little water, which will dissolve out the pyin, and at the same time cause the coagulation of the albumen. The aqueous solution thus obtained is to be separated from the insoluble portion; evaporated to dryness in a platinum capsule on a water bath; and the weight of the dry residue having been noted, it is to be incinerated. The difference between the weight of the dry residue previous to incineration, and that of the inorganic ash, represents the amount of PYIN in the portion of pus used in the experiment.

686. The matter which remained insoluble in the hot water (685), is now to be dried and weighed. The dry

residue is incinerated; and the loss of weight which it experiences during incineration will show the amount of ALBUMEN AND CORPUSCLES in the quantity of pus operated on.

687. *Treatment of the portion B.*—The weight of this portion having been noted, it is to be evaporated to dryness on a chloride-of-calcium bath, at a temperature of about 220°, the heat being continued until it ceases to lose weight on being weighed at intervals of half an hour or an hour. The loss of weight during the evaporation, will then represent the proportion of WATER in the quantity of pus employed; while the weight of the dry residue shows the amount of SOLID MATTER.

688. The dry residue is now to be incinerated in a platinum capsule or crucible, until the ash becomes white or pale grey. The weight of the ash will then show the amount of inorganic SALINE MATTER in the quantity of pus used in the experiment.

689. The proportion of the several constituents contained in 1000 parts of pus may then be estimated from the numbers obtained in the above experiments, by the following calculation:—

{Wt. of pus used in the experiment} : {Wt. of each constituent obtained} :: 1000 : {Proportion of that constituent in 1000 parts of pus.}

690. From the analysis of Dr. Wright, the composition of pus appears to be as follows:

	Pus from a vomica.	Pus from a psoas abscess.	Pus from a mammary abscess.
Water	894.4	885.2	879.4
Fatty matter	17.5	28.8	26.5
Cholesterin	5.4		
Mucus	11.2	6.1	
Albumen	68.5	63.7	83.6
Lactates, carbonates, and phosphates of soda, potash, and lime	9.7	13.5	8.9
Iron	a trace.		
Loss	3.3	2.7	1.6

CHAPTER VII.

BONE.

SECTION I.

General Characters of Bone.

691. The colour, texture, specific gravity, and general characters of bone differ very much in different parts of the body; and the proportions of the several chemical ingredients are also found to vary considerably. The two principal constituents of bone are cartilage ($C_{96}H_{82}N_{15}O_{36}$), and phosphate of lime ($8CaO,3PO_5$); the proportion of the first being usually about 29 to 34 per cent., and that of the latter from 50 to 60 per cent. of the entire bone. The other substances, which are present in smaller quantity, are, carbonate of lime (CaO,CO_2); phosphate of magnesia ($2MgO,HO,PO_5$); fluoride of calcium (CaF); soluble soda salts, chiefly chloride of sodium; traces of the oxides of iron and manganese, and fat; which latter, however, does not belong strictly to the bone, but to the marrow contained in it. The presence of these several substances may be demonstrated by the following experiments.

692. The cartilaginous matter of bone may be obtained almost entirely free from the saline and other ingredients, by digesting a bone for a day or two, at a temperature not higher than about 50°, in dilute hydrochloric acid, composed of about one part of the strong acid and five parts of water. The earthy and saline matters gradually dissolve in the acid, leaving the cartilage unaffected, and still retaining the exact form of the bone. In this state it is soft and elastic; becoming, when dried, hard, somewhat brittle, and horny in appearance.

693. If the cartilage be boiled for some time in water, it will almost wholly dissolve, being converted into gelatine ($C_{96}H_{82}N_{15}O_{36}$); leaving undissolved nothing more than a delicate network of vessels. The aqueous solution thus obtained becomes, unless very dilute, gelatinous on cooling.

694. The fat may be separated by boiling a few fragments of crushed bone with ether, and evaporating the etherial solution; when the fat will be left behind as a residue.

695. The phosphate of lime and phosphate of magnesia may be isolated by dissolving a fragment of calcined bone in dilute hydrochloric acid, and supersaturating the acid solution with ammonia; which will throw down a white gelatinous precipitate of the mixed earthy phosphates. If this precipitate be examined under the microscope, it will be found to be chiefly composed of amorphous particles of phosphate of lime, mixed with a small quantity of the crystalline double phosphate of ammonia and magnesia ($2MgO,NH_4O,PO_5+12Aq$), showing the presence of phosphate of magnesia.

696. The presence of carbonic acid (carbonate of lime) may be proved by the effervescence which ensues when a fragment of uncalcined bone is moistened with dilute hydrochloric acid. If the solution, filtered from the precipitate of earthy phosphates (695), be tested with oxalate of ammonia, it will be found still to contain a considerable amount of lime (47 *b*), which existed in the bone as carbonate; since that portion only of the lime was precipitated by the ammonia, which was in combination with phosphoric acid.

697. If calcined bone, reduced to powder, be boiled for some little time in a test tube or glass flask, with a little rather dilute sulphuric acid, consisting of about equal parts of the strong acid and water, the inner surface of the glass will generally be found to be slightly corroded, owing to the disengagement of hydrofluoric acid (HF) by the action of the sulphuric acid on the fluoride of calcium. $CaF+HO,SO_3=CaO,SO_3+HF$. This substance, however, does not appear to be invariably present in bone, and some observers have been unable to detect it.

698. The presence of chloride of sodium may be shown by boiling a little calcined bone reduced to powder, with water, filtering from the insoluble earthy portion, and testing a few drops of the aqueous solution with nitrate of silver, which will give an abundant precipitate of the chloride (AgCl). By concentrating the rest of the solution to a small bulk, and testing it with antimoniate of potash, a white crystalline precipitate of antimoniate of soda (NaO,SbO_5) will gradually appear, showing the presence of soda.

699. A little sulphate of soda may also be detected, by

means of chloride of barium (41 *c*), in the soluble portion of calcined bone, though no trace of sulphuric acid is to be found in it previous to calcination, being produced during ignition, by the oxidation of the sulphur contained in the tissues.

SECTION II.

Quantitative Analysis of Bone.

700. About three hundred grains of the bone intended for analysis should be first cleaned from adhering fat, periosteum, and other impurities, and then reduced to tolerably small fragments either by crushing or rasping.

701. *Treatment of the first portion.*—One hundred grains of the bone are to be dried in a counterpoised platinum capsule or crucible, on a chloride-of-calcium bath, at a temperature of about 250°, until it ceases to lose weight on being weighed at intervals of half-an-hour or an hour. The loss of weight which it experiences during desiccation represents the per-centage of WATER.

702. The dry mass is now to be incinerated in the capsule at a low red heat, until the whole of the organic matter is burnt away, and the ash becomes throughout perfectly white. The weight of this ash gives the per-centage of INORGANIC MATTER contained in the bone; while the loss during incineration represents the per-centage of ORGANIC MATTER. The inorganic residue may then be digested in dilute hydrochloric acid, and retained for subsequent examination (706).

703. *Treatment of the second portion.*—A second portion of the crushed or rasped bone, weighing one hundred grains, is to be digested for a day or two, in cold dilute hydrochloric acid, containing one part of the strong acid to five or six of water; the whole being kept at a temperature not higher than about 50°, as otherwise some traces of the animal matter of the bone would be acted upon by the acid. The whole, or at least by far the greater portion of the inorganic matter is thus dissolved, and when the acid liquid has been well washed out of the insoluble residue by means of cold water, little will remain but the cartilaginous matter of the bone.

704. The cartilaginous residue is to be evaporated to dryness, or nearly so, on a water bath, and then boiled with a little ether, which must be poured off, and renewed if necessary, until all the fat is dissolved. The etherial solution is then evaporated to dryness in a counterpoised capsule on a water bath; when the weight of the residue will give the per-centage of FAT in the bone.

705. The matter which proved insoluble in the ether (704), consisting chiefly of cartilage, with traces of inorganic matter, is now to be dried on a chloride-of-calcium bath, at a temperature of about 250°, weighed and incinerated. The difference between the weight of the dry residue before and after incineration, will then represent the per-centage of CARTILAGE in the bone.

706. The ash left after the incineration of the first hundred grains of bone (702), is now to be dissolved in moderately dilute hydrochloric acid; a gentle heat being applied if necessary. The acid solution is then slightly supersaturated with ammonia, which will throw down the phosphate of lime, together with the small quantity of phosphate of magnesia and fluoride of calcium; as well as any traces of peroxide of iron and oxide of manganese that may be present. The precipitate is to be well washed, filtered, dried, and ignited; after which its weight will represent the amount of BONE EARTH, consisting of PHOSPHATE OF LIME with PHOSPHATE OF MAGNESIA, and FLUORIDE OF CALCIUM, in one hundred parts of the bone.

707. If it is required to determine separately the proportion of phosphate of magnesia, the ignited precipitate (706), after being weighed, is to be redissolved in dilute hydrochloric acid; the acid solution is then mixed with an excess of perchloride of iron (Fe_2Cl_3) and supersaturated with ammonia. The phosphoric acid of the earthy phosphates is thus precipitated in combination with peroxide of iron, together with any excess of uncombined peroxide of iron, leaving in solution the chlorides of calcium and magnesium (Prac. Chem. 569). The lime (chloride of calcium) is first precipitated by adding oxalate of ammonia (NH_4O,C_2O_3) as long as it causes a precipitate, boiling the mixture, and filtering. The filtered solution is then concentrated by evaporation, and the magnesia thrown down by adding phosphate of soda ($2NaO,HO,PO_5$) and a decided excess of ammonia. The mixture is allowed to stand for some

hours, after which the precipitated double phosphate of ammonia and magnesia ($2MgO,NH_4O,PO_5+12Aq$) is to be filtered, dried, and ignited, by which it is converted into phosphate of magnesia ($2MgO,PO_5$), and weighed. This weight will represent the amount of PHOSPHATE OF MAGNESIA in the 100 grains of bone, which, when deducted from the whole earthy phosphates (706), will give the percentage of PHOSPHATE OF LIME.

708. The solution filtered from the precipitate of earthy phosphates (706), containing the portion of lime which existed in the bone as carbonate, is now to be treated with oxalate of ammonia as long as any precipitate is produced. The whole of the lime is thus separated as oxalate (CaO,C_2O_3+2Aq), which, after boiling the mixture, is filtered, dried, and ignited. The oxalate is converted, during the ignition, into carbonate (CaO,CO_2), so that the weight of the ignited precipitate will represent the amount of CARBONATE OF LIME in the hundred grains of bone.

709. As a check upon the estimation of the carbonate of lime, the amount of carbonic acid in the bone may be determined by placing 100 grains of the unburnt bone in fine powder, in a flask *a*, provided with a desiccating tube *b*, containing fragments of chloride of calcium (Fig. 71). A test tube (*c*) containing hydrochloric acid is then placed in the flask, and the whole apparatus is weighed; after which the acid is allowed to flow gradually upon the powder, from which it will expel the CARBONIC ACID. The amount of the latter, which, being gaseous, escapes in a dry state through the chloride-of-calcium tube *b*, is then represented by the loss of weight which the apparatus with its contents experiences during the experiment (337). It will probably be found that the carbonic acid thus determined, bears to the carbonate of lime (708) the proportion of 22 to 50, those being the atomic weights of carbonic acid and carbonate of lime respectively.

Fig. 71.

710. The solution filtered from the oxalate of lime (708), which contains the soluble salts (chiefly chloride of

sodium), together with the excess of oxalate of ammonia employed to precipitate the lime, is now to be evaporated to dryness, and the residue ignited in order to expel the ammoniacal salts. The weight of the residue after ignition will then represent the per-centage of SOLUBLE SALINE MATTER.

711. The following analyses will serve to illustrate the composition of bone, both of man and some of the lower animals.

Analysis I. (*Von Bibra.*)

Showing the composition of the bones of a child two months old.

	Tibia.		Ulna.
Phosphate of lime, with a little fluoride of calcium	57.54	...	56.35
Carbonate of lime	6.02	...	6.07
Phosphate of magnesia	1.03	...	1.00
Soluble salts	0.73	...	1.65
Cartilage	33.86	...	34.92
Fat	0.82	...	1.01

Analysis II. (*Von Bibra.*)

Composition of the bones of a middle-aged man.

	Femur.		Tibia.		Humerus.		Costa.
Phosphate of lime with a little fluoride of calcium	59.63	...	58.95	...	59.87	...	55.66
Carbonate of lime	7.33	...	7.08	...	7.76	...	6.64
Phosphate of magnesia	1.32	...	1.30	...	1.09	...	1.07
Soluble salts	0.69	...	0.70	...	0.72	...	0.62
Cartilage	29.70	...	30.42	...	29.28	...	33.97
Fat	1.33	...	1.55	...	1.28	...	2.04

Analysis III. (*Berzelius.*)

Composition of human bone.

Phosphate of lime	51.04
Fluoride of calcium	2.00
Carbonate of lime	11.30
Phosphate of magnesia	1.16
Soda, with a little chloride of sodium	1.20
Cartilage	32.17
Vessels	1.13

Analysis IV. (*Von Bibra.*)

Composition of the bones of the lower animals.

	Femur of sheep aged 4 years.	Femur of bull aged 4 years.	Femur of horse aged 6 years.	Humerus of cat aged 6 years.
Phosphate of lime with a little fluoride of calcium	55.94	54.07	54.37	59.30
Carbonate of lime	12.18	12.71	12.00	10.69
Phosphate of magnesia	1.00	1.42	1.83	1.70
Soluble salts	0.50	0.80	0.70	0.40
Cartilage	29.68	29.09	27.99	27.21
Fat	0.70	1.91	3.11	0.70

	Vertebræ of dolphin.	Humerus of thrush.	Vertebræ of snake.	Vertebræ of salmon.
Phosphate of lime with a little fluoride of calcium	52.51	62.65	59.41	36.64
Carbonate of lime	9.37	6.05	7.82	1.01
Phosphate of magnesia	0.98	0.90	1.00	0.70
Soluble salts	1.24	0.84	0.73	0.83
Cartilage	33.97	28.02	24.93	21.80
Fat	...	1.54	6.11	38.82

SECTION III.

Morbid Bone.

712. Certain diseases are found to be always accompanied by remarkable changes in the chemical composition of the bones; the earthy matter being sometimes so deficient, that they no longer possess the rigidity and strength necessary for sustaining the weight of the body. Other variations also are occasionally met with, a few examples of which are subjoined.

Analyses of the Tibiæ of three rachitic children. (*Lehmann.*)

	I.	II.	III.
Phosphate of lime	32.04	26.94	28.13
Carbonate of lime	4.01	4.88	3.75
Phosphate of magnesia	0.98	0.81	0.87
Chloride of sodium	0.21	0.27	0.28
Soda	0.54	0.81	0.73
Cartilage	54.14	60.14	58.77
Fat	5.84	6.22	6.94

Analyses of bone in osteomalacia. (*Prösch.*)

	Vertebra.	Costa.
Phosphate of lime	13.25	33.66
Carbonate of lime	5.95	4.60
Sulphate of lime and phosphate of soda	0.90	0.40
Cartilage	74.64	49.77
Fat	5.26	11.63

Analyses of carious bone. (*Valentin.*)

	Vertebræ of a man aged 20.	
Phosphate of lime	33.914	34.383
Carbonate of lime	7.602	6.636
Phosphate of magnesia	0.389	1.182
Chloride of sodium	3.157	1.919
Carbonate of soda	0.118	
Organic constituents	54.830	55.880

Analysis of necrotic bone of a middle-aged man.
(Von Bibra.)

Phosphate of lime with a little fluoride of calcium	72.63
Carbonate of lime	4.03
Phosphate of magnesia	1.93
Soluble salts	0.61
Cartilage	19.58
Fat	1.22

CHAPTER VIII.

EXAMINATION OF MIXED ANIMAL FLUIDS.

713. On account of the infinite number and variety of organic substances which may enter into the composition of such a mixture as we are now considering, it is altogether impossible to lay down any general and consecutive scheme of experiments, which shall comprise all even of the more commonly occurring organic compounds. All that I shall attempt, therefore, in the present chapter, is to describe very briefly the methods of detecting the presence of a few of the substances which are most frequently met with in organic liquids, and which are of the most practical importance to the pathologist and the physician.

714. The colour, consistence, and general appearance of the fluid should be first carefully observed, as the presence of many substances, such as blood, mucus, fat, fibre, &c., may often be readily detected, even with the naked eye. Should any solid or semi-solid matter be held in suspension in the liquid, or be found as a sediment at the bottom, it should be separated, either by decantation, or by filtering through fine muslin or paper.

715. The matters thus separated from the fluid may be reserved for examination under the microscope, and also, if necessary, with other tests. The following substances, among others, may in this way be readily detected:—muscular fibre, and other organized tissues; epithelium

(328); mucus and pus granules (329); fat and milk globules (325, 632, 633); infusoria of several kinds; besides various amorphous and crystalline substances, many of which may at once be recognised by their peculiar form and appearance (315—332, &c.).

716. The liquid may first be tested with litmus and turmeric paper, since the behaviour of several of the substances about to be noticed, with reagents, will be found to vary according as the liquid containing them is acid, alkaline, or neutral.

717. The specific gravity may also be ascertained, when it can conveniently be done, as a knowledge of the density of the fluid will serve to furnish some indication of the amount of solid matter held in solution (278).

Fibrin.

718. When fibrin, in the soluble state, is contained in a liquid, it gradually undergoes spontaneous coagulation, and separates from the solution, forming a more or less firm coagulum or jelly; and if other matters are held in suspension in the liquid previous to the coagulation, they are usually entangled in it,—a familiar instance of which is afforded by the coagulation of blood (473). If the liquid is decidedly alkaline to test paper, it should be neutralized with a little dilute acid, as the excess of alkali would otherwise have the effect of preventing the coagulation, since fibrin is soluble in alkaline liquids (474). The more important peculiarities of fibrin have been already noticed in paragraphs 472 to 481.

Albumen.

719. When albumen is suspected to be present in solution, the clear liquid is to be gently boiled for a few minutes; if coagulation takes place, and if the white precipitate thus occasioned does not disappear on the addition of a few drops of nitric acid, albumen is present. If the mixture is alkaline, it should be neutralized with nitric acid previous to boiling, since any excess of alkali would tend to retain the albumen in solution, and thus prevent the coagulation. For further particulars respecting albumen, and its behaviour with reagents, see paragraphs 133, 235, 466, &c.

Casein.

720. Casein may be recognised by its forming a white curdy precipitate, when the solution containing it is neutralized, or very slightly supersaturated with acetic acid. It redissolves, however, if the acid be added in decided excess. If the liquid is slightly acid to test paper, casein hardly need be looked for, since it is not soluble in acid solutions, unless the acid is present in considerable excess. It may be distinguished from albumen by not coagulating when heated; it forms, however, a thin insoluble pellicle on the surface, when exposed to the air while hot,—of which a familiar example is afforded in the skin of boiled milk. If casein be dissolved in acetic or any other acid, it is precipitated on the addition of ferrocyanide of potassium, thus resembling the other modifications of protein (625).

Pyin.

721. This substance, which appears to be identical with the tritoxide of protein, and is consequently closely allied to the other protein compounds, may be recognised by its throwing down a precipitate with acetic acid, which does not redissolve in an excess of the acid. A solution of alum also causes a white precipitate, insoluble in excess; in which respect pyin differs from glutin and chondrin (725, 726). Unlike most of the protein compounds, it is not precipitated by ferrocyanide of potassium.

Pus.

722. When pyin has been detected in a liquid, it is not improbable that, on examination with the microscope, the peculiar pus granules (678) will also be found to be present, since pyin is one of the characteristic constituents of the fluid portion of pus (676). The principal characters of this substance, together with the modes of its detection, have been already described in paragraphs 153, 247, 674, &c.

Mucus.

723. If much mucus is present, it gives to the mixture a more or less tenacious and ropy consistence, which is very characteristic. Under the microscope the peculiar mucus corpuscles, as well as the fragments of epithelium which

usually accompany them, will also probably be apparent (Fig. 5); and these, in conjunction with the ropiness above alluded to, are generally sufficient evidence of the existence of mucus. When present only in minute quantity, and especially when mixed with pus, it is often extremely difficult, if not impossible, to identify it with any degree of certainty. (See also paragraphs 31, 99, 210, 660, &c.)

Gelatine; Glutin or Collin; Chondrin.

724. These substances, which are formed by boiling the cartilaginous tissues in water, closely resemble each other in many respects; and their hot aqueous solutions all become gelatinous on cooling. Glue, isinglass, and the several varieties of gelatine, met with in commerce, are all modifications of these principles. Both glutin and chondrin are immediately precipitated, even in very dilute solutions, by a solution of tannin. They are not precipitated by ferrocyanide of potassium; in which respect they differ from the protein compounds. They are thrown down from their strong solutions by alcohol, in the form of a white tenacious precipitate; and creosote causes their solutions to become turbid and gelatinous.

725. *Glutin*, which is obtained by boiling in water, for some hours, the cartilage of bone, tendons, skin, &c., is characterized by giving with acetic acid a very slight precipitate, which readily redissolves in an excess of the acid. A solution of alum gives with glutin no precipitate; or if a slight opalescence is occasioned, it disappears on the addition of a further quantity of the precipitant.

726. *Chondrin*, on the other hand, which is formed by boiling in water any of the permanent cartilages, as those of the larynx, ribs, &c., is immediately precipitated by acetic acid, and an excess of the acid does not redissolve it. Alum, too, causes a precipitate, which, however, readily dissolves when the salt is added in excess. The solubility of gelatine in a solution of alum serves to distinguish it from pyin (721).

Blood.

727. The colour which it imparts to any liquid with which it is mixed is usually almost sufficient evidence of the presence of blood, unless the quantity is very small.

The red corpuscles may also, in most cases, be detected under the microscope, more or less altered in form and size by the action of the fluid in which they float (456,583). When blood is present, albumen also will be found dissolved in the liquid, unless it has been previously coagulated by heat or otherwise; it may be detected by the application of heat, and nitric acid, in the manner described in paragraphs 235, 236, &c.

Biliary Matter.

728. Biliary matter, if present in any considerable quantity, generally communicates a more or less decided brown or yellowish colour to the liquid, and also a peculiar bitter taste. It may be identified by means of Heller's and Pettenkofer's tests, described in paragraphs 149 & 151. If these fail to detect it in the fluid, a little of the latter may be evaporated nearly to dryness on a water bath, and a strong aqueous solution of the residue, tested as before.

Urea.

729. This substance may be detected in organic liquids, in the following manner:—The portion of the organic mixture intended for the examination, is evaporated to dryness at a gentle heat on a water bath, and the dry residue treated with alcohol, which will dissolve out any urea that may be present, together probably with some other of the matters with which it is associated. The alcoholic solution is then evaporated to dryness, and the dry extract digested with a very small quantity of moderately warm water; which will readily dissolve out the urea. The aqueous solution thus obtained is then mixed, after filtering, with pure nitric acid, in the manner described in paragraph 16, and then cooled by means of a freezing mixture; when, if urea is present, delicate crystals of the nitrate (Fig. 2) will gradually appear. When the quantity of urea is very small, the microscope may be employed to detect any traces of the crystalline nitrate, and some other precautions must be observed, which have been described in paragraphs 181—184, 341, &c.

Fat.

730. When any considerable amount of fatty matter is present in an aqueous mixture, it may be readily detected

with the naked eye, and still more delicately under the microscope, by the appearance of oily or fatty globules floating on the surface. When, however, the quantity is very small, or, owing to other circumstances, no appearance of fat is to be seen; a little of the mixture suspected to contain it, is to be evaporated nearly to dryness on a water bath, and the residue digested with a little warm ether, which will readily dissolve any traces of fatty matter that may be present. On evaporating the etherial solution on a water bath, the oil or fat will be left as a residue, and may be identified by its possessing the well-known physical characters of fatty matters (158).

731. The saponifiable fats most commonly met with in animal fluids are, oleine ($C_{78}H_{75}O_{13}$), stearine ($C_{142}H_{141}O_{17}$), margarine ($C_{74}H_{74}O_{12}$), and butyrine. The degree of hardness or oiliness, and the temperature to which the fatty matter requires to be raised before it melts, serve to furnish some indication as to the relative amounts of the solid stearine and the oily oleine. Butyrine may generally be detected by the peculiar smell which it gradually acquires, resembling that of rancid butter.

Cholesterin and Serolin.

732. If either of these substances are present, they will have been dissolved by the ether (730), together with any other fatty matters that may be contained in the liquid. They may be separated from the other fats by digestion with a solution of potash, which will dissolve out the saponifiable fats, and leave the cholesterin and serolin unaffected (596). These may be distinguished from each other by their different fusing points, that of cholesterin being 278°, while that of serolin is as low as 97°.

Milk.

733. The well-known physical characters of milk are generally sufficiently apparent to lead to its detection, unless largely diluted with other matters. When any doubt exists as to its presence, a drop of the liquid may be examined under the microscope for the milk globules (632); and the clear liquid, after filtration, may be tested with acetic acid for casein (623), the existence of which, in any fluid, is strong evidence of the presence of milk. The residue left by

evaporating the liquid to dryness, may be tested for fat also, by digestion with warm ether, and evaporating the etherial solution on a water bath (730).

Sugar.

734. The most convenient test for the presence of sugar is that known as Trommer's, which has already been fully described in paragraphs 122 to 125. The fermentation test (127) may also, in many cases, be employed with advantage; and, indeed, it is always more satisfactory to confirm the results of Trommer's experiment, by applying also the fermentation test; since the suboxide of copper may be sometimes produced by certain other organic substances, even when no sugar is present. If the sugar is present only in very minute quantity, it may be advisable to evaporate the liquid to dryness on a water bath, and redissolve the soluble portion of the residue, including the sugar, in a small quantity of hot water, in the manner described in the process for detecting sugar in the blood (606). The strong aqueous solution may then be examined by Trommer's, and the other tests.

735. When cane sugar is suspected to be present, the solution should first be boiled for a few minutes with dilute sulphuric acid before the application of Trommer's test, in order to convert it into grape sugar; since the cane variety does not otherwise produce the same characteristic results.

Ammonia.

736. This substance, which is so constantly to be met with in animal fluids, as one of the results of the decomposition of nitrogenous compounds, may be readily detected, even when present in very small quantities. A portion of the liquid is mixed in a test tube with a little caustic potash, or still better, with caustic baryta (note to 38), and warmed. The ammonia, if present, is thus disengaged, and may be detected by the smell, or still more delicately, by holding, at the mouth of the tube, a glass rod moistened with dilute hydrochloric acid, when white fumes of muriate of ammonia will be distinctly visible.

737. If the ammonia is present only in minute quantity, a little of the suspected liquid may be mixed with a few

drops of dilute sulphuric acid, in order to fix the ammonia, and then concentrated by evaporation at a gentle heat on a water bath; the concentrated liquid may then be supersaturated with potash or baryta, and examined in the manner above described.

Uric (or lithic) acid.

738. When an organic mixture is suspected to contain uric acid, it may, if free from albuminous matter, be acidified with a few drops of hydrochloric acid, and allowed to stand a short time. The uric acid will gradually separate in the form of minute crystals (20), which may be examined under the microscope, and also tested with nitric acid and ammonia, in the manner described in paragraph 23. If any albuminous matter is mixed with the liquid, the latter is to be evaporated to dryness on a water bath, and the residue digested with a dilute solution of caustic potash. The alkaline solution is then supersaturated with a decided excess of hydrochloric acid, which will throw down the uric acid in the form of a crystalline precipitate. If the quantity is small, a drop of the liquid may be mixed with the acid on a strip of glass, and examined for the characteristic crystals under the microscope (318).

739. The principal characters of uric acid, and the methods of detecting and estimating it in the urine, have been already noticed in the several chapters of Part I.

PART V.

THE DETECTION OF POISONS IN ORGANIC MIXTURES, &c.

CHAPTER I.

ARSENIC.

740. Although all, or nearly all, the compounds of arsenic appear to be more or less intensely poisonous, I shall here allude especially to the detection of arsenious acid (AsO_3); since in the vast majority of cases in which arsenic is taken, whether criminally or accidentally, it is in the form of arsenious acid, or as it is often called, oxide of arsenic, or white arsenic. The experiments which I am about to describe will serve, however, for the most part, equally well for identifying the presence of arsenic in other forms of combination than that of arsenious acid; so that, if the processes are carefully conducted, the risk of any traces of the metal escaping detection is very small.

741. When the presence of the sulphide of arsenic (AsS_3) is suspected, the substance supposed to contain it may be first examined for any particles of yellow powder; which, if present, should be mixed, when dry, with a little black flux, and heated in a small German glass tube, closed at one end; when, if it consists of sulphide of arsenic, a crust of the metal will appear in the upper part of the tube (743). If no yellow powder can be detected, the mass in which it is suspected to be present is to be boiled with nitrohydrochloric acid, when the sulphide will become converted into arsenic acid (AsO_5), which will remain in solution, and may be detected by Reinsch's, or Marsh's test (749, 745).

SECTION I.

Detection of Arsenious Acid when unmixed with other substances.

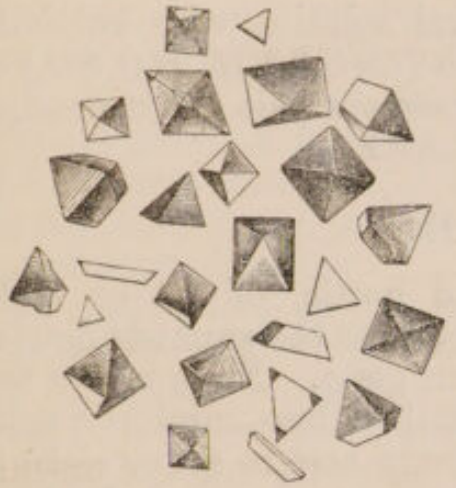

Fig. 72. Arsenious acid.

742. Place a little of the white powder in a small tube of German glass, closed at one end, and heat it gradually with the blowpipe, or in the flame of a spirit lamp. If it is arsenious acid, it will sublime, and condense in the upper part of the tube, forming a colourless crystalline sublimate, which, when examined with a good lens or microscope, will be found to consist of beautiful sparkling octohedral crystals (Fig. 72).

743. Mix a little of the suspected powder with black flux, which for this purpose should be perfectly dry, and heat the mixture in a small tube of German glass before the blowpipe. If arsenic is present, it will be reduced to the metallic state, and sublime into the upper part of the tube, forming a shining metallic crust (*a*, Fig. 73). The tube may then be broken, and fragments of the crust placed in another tube, and again heated. The reduced metal will in this way be reconverted into arsenious acid, crystals of which will condense in the cool part of the tube (742).

Fig. 73.

744. Make a solution of some of the powder in hot water, in which arsenious acid is sparingly soluble, and apply to separate portions of the solution the following tests. (See also 745 & 749.)

(*a*) Acidify a portion of the solution with a drop or two of hydrochloric acid, and pass a current of hydrosulphuric acid gas (sulphuretted hydrogen) through the liquid, until it smells distinctly of the gas. If arsenic is present, a

bright yellow precipitate of sulphide (AsS_3) will be thrown down.

(*b*) Add to a second portion of the neutral solution a few drops of nitrate (AgO,NO_5), or, still better, ammonio-nitrate ($AgO,2NH_3,NO_5$) of silver. If arsenic is present, a canary-coloured precipitate of arsenite of silver ($2AgO, AsO_3$) will be thrown down, which is soluble in nitric acid and also in ammonia.

(*c*) Test a little of the neutral solution with sulphate (CuO,SO_3) or ammonio-sulphate ($CuO,2NH_3,HO,SO_3$) of copper. This will cause, with arsenic, a pale green precipitate of arsenite of copper ($2CuO,AsO_3$).

Marsh's Test.

745. Arrange a wide-mouthed bottle, of six or eight ounces' capacity, with tubes as shown in the annexed figure; the tube *d* being of hard German glass. Place in it a few fragments of zinc, and add a little dilute sulphuric acid, consisting of one part of the strong acid to six or eight of water. When the hydrogen has been coming off about five minutes,* apply a light to the gas as it issues from the aperture at *e*, and hold over it, or rather *in* it, a clean porcelain crucible lid, in order to prove whether any traces of arsenic are contained in the zinc or acid employed, in which case a more or less distinct arsenical stain would be produced. If the materials are thus found to be pure, a little of the solution of the supposed arsenic is to be introduced through the tube *b*.

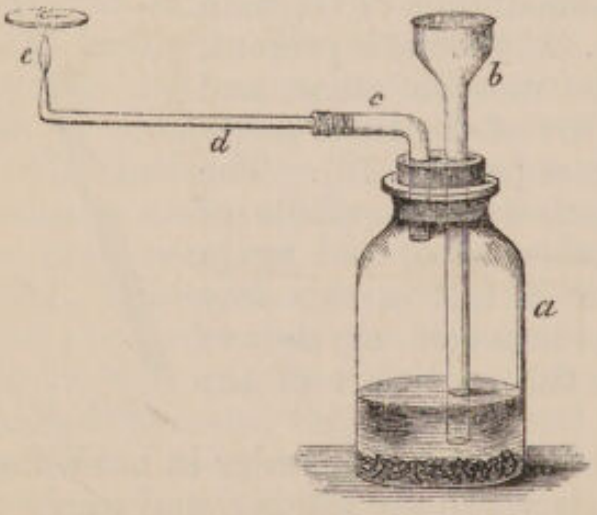

Fig. 74.

746. Again apply a light to the jet of gas at *e*, and hold in the flame a clean porcelain crucible lid. If arsenic is

* This interval must be allowed to elapse, in order that the whole of the common air in the apparatus may be expelled before the light is applied; since a mixture of hydrogen and common air is highly explosive.

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oxidized and converted into arsenious acid, crystals of which will appear in the cool part of the tube.

Reinsch's Test.

749. Acidify a little of the aqueous solution of the substance suspected to contain arsenic, with a few drops of pure hydrochloric acid,* and boil in it two or three strips of clean copper foil. If arsenic is present, it will be deposited in the metallic state on the surface of the copper, and may be proved to be arsenic in the following manner.

(*a*) Dry the copper strips by gentle pressure between folds of filtering paper, or by warming them on a water bath; when dry, place them in a small clean and dry tube of German glass, closed at one end, and apply the heat of the blowpipe. The arsenic will volatilize; and becoming oxidized while in contact with the air, arsenious acid will condense in the upper part of the tube, forming a crystalline sublimate, which may be examined with a lens (742).

(*b*) Dissolve the sublimate obtained in *a*, in a little hot water, and apply to the solution the tests described in paragraph 744.

SECTION II.

Detection of Arsenic in liquids containing organic matter.

750. When the liquid suspected to contain arsenic is tolerably clear, and unmixed with solid matter, it should be acidified with a little pure hydrochloric acid, (the purity of which has been previously ascertained (Note to 749),) and then boiled with two or three small strips of copper foil or wire gauze. If arsenic is present it will probably be deposited, in the course of a few minutes, upon the surface of the copper, and must be treated in the manner presently to be described (751). It must not, however, be considered certain that no arsenic is contained in the liquid, until after boiling the mixture for half an hour, or even longer; when,

* The acid employed for this purpose, must be first proved to be free from all traces of arsenic, which is frequently present in small quantities in the hydrochloric acid of commerce. This is readily ascertained by boiling a little of the diluted acid with strips of copper, which may then be examined for arsenic in the manner described in paragraph 749, *a*.

if no stain is produced which, on examination, gives indications of arsenic, it may safely be concluded that no trace of the metal is present.

751. It occasionally happens that a little fatty animal matter is deposited on the surface of the copper during the boiling. When this is the case, the copper should be boiled with a little ether or alcohol, in order to dissolve it, before being exposed to heat in the tube.

752. The copper strips must now be heated in a small clean and dry tube, closed at one end; when, if any arsenic has been deposited upon them, a crystalline sublimate of arsenious acid will appear in the upper part of the tube. If, on examination with a lens, the sublimate is found to exhibit the characteristic crystalline form and appearance of arsenious acid (742), there can scarcely be a doubt of the existence of arsenic. It is, however, always advisable, in cases of medico-legal investigation, to obtain the combined testimony of other experiments, in order to obviate the possibility of error.

753. For this purpose, the white sublimate is to be removed from the surface of the glass with a clean knife, and divided into three portions, A, B, & C.

(*a*) Mix the portion A, which should be previously dried on a water bath, with a little dry black flux, and heat the mixture in a clean narrow tube, closed at one end. A crust of metallic arsenic ought to be produced in the cool part of the tube (743).

(*b*) Dissolve the portion B in a little water acidified with hydrochloric acid, and apply Marsh's test, in the manner described in paragraphs 745—748.

(*c*) Dissolve the portion C in hot water, and divide the solution into three parts, which may be tested respectively with hydrosulphuric acid, ammonio-nitrate of silver, and ammonio-sulphate of copper, as directed in paragraph 744, *a*, *b*, & *c*.

SECTION III.

Detection of Arsenic in organic mixtures containing both liquid and solid matters; such as the contents of a stomach, vomited matters, &c.

754. When the liquid and solid portions of the mixture are found capable of ready separation, either by subsidence

or filtration, it is generally better to examine each of them separately. When this is not the case, see paragraph 758.

755. *Examination of the liquid portion.*—The clear liquid, after the removal of the solid matter, either by filtration or otherwise, is to be acidified with a little pure hydrochloric acid, and boiled with a few strips of clean copper; which, after being dried between folds of filtering paper, are to be heated in a dry tube, and the sublimate, if any, examined in the manner described in paragraph 749.

756. *Examination of the solid portion.*—This should first be examined for any small lumps of arsenious acid, which, in cases of poisoning, are often to be found adhering to the coats of the stomach. These should be carefully picked out, and tested according to the directions given in paragraphs 742—744.

757. The solid or semi-solid organic matter is then to be boiled with dilute hydrochloric acid, containing about one-tenth of the strong acid, which will dissolve any arsenious acid that may be present. The acid solution is then filtered from any solid matter that may have remained undissolved, and boiled with copper strips, which are to be dried, and examined for arsenic in the manner before described (749).

758. When the organic matter is viscid, and incapable of ready separation into solid and liquid portions (754), it may be mixed with a little dilute hydrochloric acid, well stirred together, and boiled; after which it is to be boiled with strips of copper, which may be subsequently examined for arsenic in the manner already described (749).

SECTION IV.

Detection of Arsenic in oily or fatty matters.

759. When arsenic is suspected to be present in fatty or oily matters, in many of which it is to a considerable extent soluble, the fat may be boiled for a quarter of an hour with dilute hydrochloric acid, containing about one-tenth of strong acid. The arsenic is thus dissolved by the acid, and the solution may be separated from the fat or oil, by filtering through a paper filter previously saturated with water. The acid solution is then boiled with strips of clean copper, which are afterwards to be dried, and examined according to the directions given in paragraph 749.

SECTION V.

Detection of Arsenic in the Tissues.

760. In medico-legal investigations as to the presence of arsenic, it is absolutely necessary, in case none of the poison can be detected in the stomach and its contents, to examine the various tissues of the body; since the poison, when introduced into the stomach during life, becomes gradually absorbed, and diffused through the whole system, and may be found in the blood, urine, muscles, and viscera, especially the liver. It is therefore advisable to examine each of these for the poison; and it should never be concluded, that because it cannot be detected in the stomach and its contents, none is to be found in other parts of the body. Should the patient, however, survive during several days after swallowing the poison, it is possible that the whole of it may be eliminated from the body; in which case no trace of it will afterwards be detected.

761. The portion of the body intended for examination* is to be cut up into thin slices, and boiled for an hour or two in dilute hydrochloric acid, consisting of one part of the strong acid to eight or ten of water. The mixture is then filtered through fine muslin, in order to separate the more solid matters; and the clear liquid thus obtained is concentrated to about half its bulk, by evaporation at a gentle heat. The acid solution is then boiled with strips of clean copper foil, which are to be subsequently examined for arsenic in the manner described in paragraph 749.

SECTION VI.

Quantitative determination of Arsenic.

762. The quantity of arsenic contained in any mixture, whether organic or otherwise, may be determined in the following manner:—After having obtained the arsenic in a

* The part of the body in which the poison is most likely to be found is the liver, which should always be preferred for these experiments. The pancreas, kidneys, and urine, should also, if possible, be examined, before deciding on the absence of arsenic.

state of solution by boiling with dilute hydrochloric acid (758), and filtering if necessary, a current of hydrosulphuric acid gas (sulphuretted hydrogen) is passed through the acid liquid for an hour or two, and the solution, after being saturated with the gas, is then set aside for a short time in a moderately warm place. The whole of the arsenic is thus thrown down in the form of sulphide (AsS_3), mixed, probably, with a little free sulphur, and perhaps traces of other impurities. In order to separate it from them, it is digested in a solution of ammonia, to dissolve out the sulphide of arsenic, which may, after filtering, be again precipitated in a state of purity, by supersaturating the ammoniacal solution with hydrochloric acid. The sulphide is then collected and washed on a filter, dried at a very gentle heat on a water bath, and weighed. From the weight of the dry precipitate the amount of metallic arsenic, or of arsenious acid, may be estimated; 100 parts of the sulphide being equivalent to 61.0 parts of metallic arsenic, or 80.5 parts of arsenious acid.

CHAPTER II.

ANTIMONY.

763. The only form in which antimony is likely to be met with in medico-legal investigations, is the double tartrate of antimony and potash ($KO,SbO_3,C_8H_4O_{10}+2Aq$), commonly called tartar-emetic, or tartarized antimony; which is often taken medicinally, and occasionally as a poison. It may be recognised by its solution giving with hydrosulphuric acid or hydrosulphate of ammonia, an orange red precipitate of sulphide (SbS_3); and by giving stains of metallic antimony when examined with Marsh's test (745, 765).

SECTION I.

Detection of Antimony in Organic Mixtures.

764. When a mixture containing organic matter, whether in the fluid or solid state, (such as the contents of a stomach,

vomited matters, &c.), is suspected to contain antimony, it should be boiled with a mixture of dilute hydrochloric and tartaric acids, which will serve to dissolve any of the compounds of antimony that may be present in the solid form. The solution is then filtered, if necessary, from any insoluble matter; and a stream of hydrosulphuric acid (sulphuretted hydrogen) is passed through the clear solution, until the latter is saturated with the gas. The antimony, if any is present, is thus precipitated as the orange sulphide, which may be separated by filtration, and dissolved in as small a quantity as possible of hot hydrochloric acid.

$$SbS_3+3HCl=SbCl_3+3HS.$$

765. The solution of chloride of antimony thus obtained may then be divided into three portions for testing.

(*a*) Try the first with Marsh's test, by adding it in a proper bottle (745) to a mixture of zinc and sulphuric or hydrochloric acid, and examining the stains with hydrosulphate of ammonia and chloride of lime. By the first of these it should be immediately dissolved; and unaffected, or nearly so, by the second (746, *b* & *c*). On applying the heat of a spirit lamp to the tube at the point *d* (Fig. 74), a deposit of metallic antimony will be produced at the heated point. Unlike the deposit formed by arsenic under similar circumstances, it will not be found to volatilize with the heat of a spirit lamp (748).

(*b*) The second portion of the acid solution may be mixed with five or six times its bulk of water; which should cause a milkiness in the solution, owing to the formation of the basic oxichloride of antimony ($SbCl_3,5SbO_3$). The precipitate thus occasioned is soluble in a solution of tartaric acid.

(*c*) The third portion may be mixed with about its own bulk of water, and saturated with hydrosulphuric acid gas, which should cause an orange precipitate of the sulphide (763). If, however, the colour of the precipitate previously thrown down by this reagent (764), was decidedly orange, and not masked by the presence of other matters, this experiment need not be performed.

SECTION II.

Detection of Antimony in the Tissues.

766. The portion of the body intended for examination (the liver being, if possible, selected (note to 761)) is to be cut into thin slices, and digested for an hour or so in a mixture of dilute hydrochloric acid (containing one part of strong acid to about eight parts of water), and tartaric acid, which should be kept gently boiling. The antimony is in this way effectually brought into solution, partly as chloride, and partly in combination with tartaric acid. The mixture may then be filtered, and the clear solution decomposed by a stream of hydrosulphuric acid gas, which will throw down the antimony in the form of the orange sulphide (764). This is to be separated by filtration, and converted into the chloride by dissolving it in a small quantity of hot hydrochloric acid; after which the acid solution may be tested in the manner described in paragraph 765.

SECTION III.

Quantitative Determination of Antimony.

767. If it is required to estimate the quantity of antimony in any organic mixture, the latter is treated in the manner described in paragraph 766, first with hydrochloric and tartaric acids, and then, after filtration, saturated with hydrosulphuric acid gas; by which the antimony is precipitated as the orange-coloured sulphide. This is then separated by filtration, dried at a gentle heat, and weighed. One hundred grains of the sulphide thus obtained is equivalent to 72.8 grains of metallic antimony, or to about two hundred grains of the double tartrate.

CHAPTER III.

MERCURY.

768. The most common preparation of mercury, by which life has been sacrificed or endangered, is the bichloride ($HgCl_2$), commonly called corrosive sublimate; the chloride, or calomel (HgCl), the red oxide (HgO_2), and some of the other compounds, are also sometimes administered, either criminally or accidentally, with fatal effect, and may consequently have to be looked for by the medical jurist. In the process I am about to describe, however, any of these compounds will be brought into a state of solution; after which the mercury contained in them may readily be detected by the proper tests.

SECTION I.

Detection of Mercury in Organic Mixtures.

769. When the presence of mercury is suspected in an organic mixture, such as the contents of a stomach, the solid and liquid portions of the matter to be examined may be separated from each other, either by filtration or decantation, provided the separation takes place readily; or if this is not the case, the whole of the mixture may be treated with acid, and examined in the manner described in paragraphs 774—776.

770. *Examination of the liquid portion.*—The liquid portion may be first examined. Acidify it with a few drops of hydrochloric acid, and boil the mixture for a quarter or half an hour, with two or three strips of clean copper foil. If any mercury is present in the liquid, it will in this way be entirely separated from the solution, and deposited on the surface of the copper. The latter is then removed from the acid liquid, and washed with a little dilute solution of ammonia, in order to remove from the surface any adhering oxide or subsalt of copper. The strips are then dried by gentle pressure between folds of bibulous paper, or still

better, at a very moderate heat on a water bath, and placed in a small and perfectly dry German glass tube, three or four inches long, closed at one end.

771. The heat of the blowpipe is then applied to the bottom of the tube containing the copper strips; when, if any mercury has been deposited upon them, it will be volatilized by the heat, and condense in the cooler part of the tube, forming a delicate and dew-like ring of minute globules of metallic mercury; the real nature of which may be at once seen with the assistance of a common lens, if not with the naked eye.

772. If in the experiment above described (771), the appearance of metallic globules is distinctly visible, it will scarcely be necessary to apply any further tests to prove the presence of mercury, since no other substance is capable of producing such a sublimate. If, however, any doubt exists as to the nature of the sublimate, the following experiments may be made:—

773. Remove the copper from the tube, and dissolve the sublimate in nitrohydrochloric acid; by which the mercury, if present, will be converted into the soluble bichloride ($HgCl_2$). Expel the excess of acid by evaporation at a gentle heat; and apply to an aqueous solution of the residue, the following tests:—

(*a*) Solution of iodide of potassium (*KI*) gives a brilliant red precipitate of periodide of mercury (HgI_2), which is soluble in an excess either of the mercurial solution or of the iodide of potassium.

(*b*) Solution of potash gives a yellow precipitate of hydrated peroxide of mercury ($HgO_2,3HO$), which is insoluble in an excess of the precipitant.

(*c*) A stream of hydrosulphuric acid gas (sulphuretted hydrogen), or a drop or two of hydrosulphate of ammonia, form at first a white precipitate, consisting of a double compound of chloride and sulphide ($2HgS_2,HgCl_2$), which, unless the precipitant be added very sparingly, almost immediately becomes darker, owing to the admixture of the black sulphide (HgS_2). If the precipitant be added in excess, the whole of the precipitate becomes black.

(*d*) The dry mercurial salt, when mixed with carbonate of soda, and heated in a narrow tube before the blowpipe, yields a sublimate of minute globules of metallic mercury.

774. *Examination of the solid portion.*—The solid portion

of the mixture may contain mercury in combination with certain animal matters, besides particles of calomel, oxide, or some other mercurial compound. It may first be examined for any visible fragments of these, which if detected, may be picked out, and tested for mercury, by mixing them, when dry, with carbonate of soda, and heating the mixture in a small tube before the blowpipe; when the mercury will be sublimed into the cooler part of the tube (773 *d*).

775. The rest of the solid matter may now be warmed with a little nitrohydrochloric acid, which will convert the oxide, or chloride, if present, into the bichloride, and thus ensure the solution of any mercurial compound that may be contained in it. The excess of acid may then be expelled by evaporating the liquid to dryness on a water bath; after which the residue is to be redissolved in a small quantity of water.

776. The solution thus obtained may now be acidified with a few drops of hydrochloric acid, and boiled for a quarter or half-an-hour with two or three strips of clean copper foil; on the surface of which the mercury, if present, will be deposited. The copper is then removed from the liquid, washed with water, and a little dilute solution of ammonia (770), and when dry, heated in a small tube of German glass, closed at one end. In this manner the mercury will be volatilized, and may be seen condensed in the upper part of the tube, forming a dew of minute metallic globules. These may, if necessary, be redissolved in a little nitrohydrochloric acid, and the solution tested in the manner described in paragraph 773.

SECTION II.

Detection of Mercury in the Tissues.

777. When the presence of mercury is suspected in the viscera or other tissues of the body, the part intended for examination should first be cut into thin slices, and boiled for a short time with a little nitrohydrochloric acid; by which means any mercury that may be present will be converted into the bichloride, and thus brought into a state of solution. The undissolved matter is then separated by

filtration or decantation, and the liquid portion evaporated to dryness on a water bath, in order to expel the excess of acid. The residue is redissolved in water, acidified with a few drops of hydrochloric acid, and boiled with copper; which must be subsequently washed with water and ammonia, and then examined for mercury, in the manner described in paragraphs 770—773.

SECTION III.

Quantitative Determination of Mercury.

778. The quantity of mercury present in any organic mixture may be determined by weighing the metal itself, obtained either by sublimation, or by boiling the liquid containing it, after being acidified with hydrochloric acid, with a solution of protochloride of tin. When protochloride of tin is used as the reducing agent (Prac. Chem. 339), the sediment of finely divided mercury should be washed with a little hydrochloric acid, separated from the liquid by filtration, and dried on the filter (the weight of which should have been previously ascertained), at a temperature not exceeding 150°; in order to prevent the loss of any mercury by evaporation. It may then be weighed in the filter, which may be kept in a covered porcelain crucible.

CHAPTER IV.

LEAD.

779. Although instances of criminal poisoning with compounds of lead are of comparatively rare occurrence, still the accidental admission of it into the system, either in the form of the solid carbonate (white lead) so extensively employed in the arts, or through the medium of water impregnated with it, very frequently leads to serious, and even fatal results; so that its detection is often a matter of grave importance.

780. In testing for minute quantities of lead, it must be borne in mind that several of the test solutions employed in analysis, when kept even for a few weeks in bottles of flint glass, dissolve out very perceptible traces of the metal from the glass, in which it is present in considerable quantity; so that, unless the experimenter is on his guard, he may be led to suppose that he has detected the metal in the liquid which he is examining, while, in fact, he has himself introduced it in one of his reagents. Solutions of potash and soda, and their carbonates, are especially liable to become in this way impregnated with lead; and several other saline solutions also, under peculiar circumstances, do the same, though more slowly, and in a less degree. On this account it is always advisable to test each of the reagents employed (previously neutralized, if strongly acid or alkaline) with hydrosulphuric acid or hydrosulphate of ammonia (781), which will, if any traces of lead are present, give the liquid a more or less decided brown tint; or even cause a black precipitate, if the quantity of metal is at all considerable.

SECTION I.

Examination of Water suspected to be impregnated with Lead.

781. The water intended for examination (which should always be tested as soon as possible after being taken from the cistern or pipe in which it has been standing) is placed in a beaker or bottle of German or green glass, free from lead, the surface of which should be washed perfectly clean with distilled water. A stream of hydrosulphuric acid (sulphuretted hydrogen) gas is then transmitted through the water, until the latter smells distinctly of the gas. When lead is present, the liquid will generally assume a brown tint almost immediately, unless the quantity of lead is extremely small; but before deciding that the water is pure, it should be set aside for a few hours, after being saturated with the gas, during which time the sulphur will be partially precipitated, owing to the decomposition of the hydrosulphuric acid by the oxygen of the air (Prac. Chem. 729), mixed, if any trace of lead is present, with a little sulphide (PbS), which will give the sediment a more or less decided brown or fawn colour. If, on the contrary, the

water continues colourless, and the precipitated sulphur is white, or of a very pale sulphur colour, it may be concluded that no perceptible trace of lead is contained in the water.

782. If, however, any uncertainty exists, half a pint of the water may be evaporated to dryness, and the residue moistened with a solution of hydrosulphuric acid, or a drop of dilute hydrosulphate of ammonia; when, if no black or even brown colour is produced, the absence of lead may be considered certain. If the residue is found to become brown or black on the application of the hydrosulphuric acid or hydrosulphate, it is *probably* owing to the presence of lead; but as a similar effect may, under certain circumstances, be produced by iron and other impurities, the residue may be moistened with a little dilute nitric acid, gently warmed, and dissolved in as small a quantity as possible of water. The solution thus obtained may then be tested for lead in the manner described in paragraphs 785—787.

SECTION II.

Detection of Lead in Organic Mixtures.

783. If the organic matter to be examined is a mixture of solid and liquid, such as the contents of a stomach, the two portions should, if practicable, be separated by filtration through paper or muslin; having been previously diluted, if necessary, with a little water, which will cause the liquid to pass more readily through the pores of the filter. The liquid portion may be first tested; and in case none of the metal can be detected in it, the solid or semi-solid matter may be afterwards examined (788).

784. *Examination of the liquid portion.*—A current of hydrosulphuric acid gas is passed through the liquid for about a quarter of an hour, by which means any lead that may be dissolved will be precipitated as the black sulphide. This is to be separated by filtration, and the greater part of it digested, with the aid of a gentle heat, in moderately dilute nitric acid; a small portion being retained for examination with the blowpipe (787).

785. When the sulphide is for the most part decomposed by the nitric acid (which may be known by the undissolved residue, consisting chiefly of sulphur, becoming nearly white), the clear solution is to be poured off the insoluble

matter, and tested in the following manner (786); the undissolved residue being also retained, in case it may be required for subsequent examination (787). The digestion in warm acid should not be continued longer than necessary, since the prolonged action of the nitric acid might have the effect of oxidizing the sulphur as well as the lead, forming sulphuric acid, which would combine with the oxide of lead, and precipitate it from the solution in the form of the insoluble sulphate (PbO,SO_3).

786. The clear solution (785) is now to be evaporated to dryness on a water bath, in order to expel the excess of nitric acid; after which the residue is to be redissolved in warm water, and tested in the following manner; or, if the quantity is small, the tests *b*, *c*, & *d* only need be applied.

(*a*) Hydrosulphuric acid and hydrosulphate of ammonia cause a black precipitate of sulphide of lead (PbS).

(*b*) Dilute sulphuric acid, or a solution of sulphate of soda, gives a white precipitate of sulphate of lead (PbO,SO_3), which is insoluble, or nearly so, in acids, but gradually dissolves in a solution of caustic potash.

(*c*) The sulphate formed in *b*, after being washed with distilled water, is instantly blackened when moistened with hydrosulphate of ammonia or a solution of hydrosulphuric acid, owing to the formation of the black sulphide. The sulphate of lead may in this way be readily distinguished from the sulphates of baryta and strontia, which it resembles in many respects.

(*d*) A solution of iodide of potassium (*KI*) throws down a bright yellow precipitate of iodide of lead (PbI), which is soluble in hot water, and, on cooling, separates from the solution in the form of brilliant crystalline scales of great beauty.

(*e*) Hydrochloric acid, or a solution of chloride of sodium, causes, if the solution is not very dilute, a white crystalline precipitate of chloride of lead (PbCl), which dissolves when the mixture is heated, and crystallizes in the form of delicate needles as the solution cools.

(*f*) Chromate of potash (KO,CrO_3) gives a rich yellow precipitate of chromate of lead (PbO,CrO_3), which is soluble in potash, and insoluble in dilute acids.

(*g*) If any of the precipitates formed in the above experiments be dried, and heated on charcoal, with or without a little dried carbonate of soda, in the inner flame

of the blowpipe (Prac. Chem. 83), minute metallic beads will be obtained; which may be recognised as lead by their softness and malleability.

787. If no decided indication of lead can be obtained from the nitric acid solution, the other portion of sulphide (784), and also the residue which proved insoluble in the acid (785), may be dried, mixed with carbonate of soda, and heated in the inner flame of the blowpipe; when, if any lead is present, it will be speedily reduced to the metallic state, forming minute malleable beads.

788. *Examination of the solid portion.*—If the examination of the liquid portion should fail in proving the presence of lead, the poison may still be sought for in the solid or semisolid matters left on the filter (783), since it may exist in combination with animal matter, or in some other insoluble form. The mixture is evaporated to dryness, and the dry mass, after being reduced to powder, is to be mixed with three or four times its weight of black flux, and carefully ignited, for about a quarter of an hour, in a covered Berlin porcelain crucible. The lead, if present, is thus reduced to the metallic state; and unless the quantity is very small, will be found in a round globule at the bottom of the crucible.

789. If a button of metal is thus produced, it may be proved to be lead by its well-known physical properties, such as softness and malleability; or by dissolving it in dilute nitric acid, and after expelling the excess of acid by evaporation, testing the solution in the manner described above (786).

790. If, however, no globules of lead are visible, the whole of the incinerated matter may be boiled with dilute nitric acid; by which any lead will be dissolved, and may be detected in the solution by the tests before described (786), after filtering from the insoluble carbonaceous residue, and expelling the excess of acid by evaporation as before.

SECTION III.

Detection of Lead in the Tissues.

791. When, in a suspected case of poisoning by lead, no trace of the metal can be detected in the contents of the

stomach, &c., it is necessary, before deciding upon the absence of the poison, to examine the tissues of the stomach, intestines, and especially the liver; since it may be often found absorbed in these tissues, even when no trace is to be met with elsewhere.

792. The portion of the body intended for examination is to be cut into thin slices, and dried; after which the dry residue is to be reduced to powder, mixed with three or four times its weight of black flux, and ignited for about a quarter of an hour in a covered Berlin porcelain crucible. The incinerated mass is then to be examined for any globules of metal; and if none of these can be found, it may be digested with dilute nitric acid in the manner described in paragraph 788, and tested for lead according to the directions already given.

SECTION IV.

Quantitative Determination of Lead.

793. When it is required to estimate the quantity of lead in an organic mixture, the metal must first be brought, if not already so, into a state of solution (788), and precipitated by means of a current of hydrosulphuric acid, which must be continued until the liquid is found to smell strongly of the gas. The sulphide (PbS) thus formed, is to be filtered, and converted into the sulphate (PbO,SO_3) by boiling with strong nitric acid; a few drops of dilute sulphuric acid being afterwards added, in order to ensure the conversion of the whole of the lead into sulphate. The sulphate of lead is then dried in a counterpoised porcelain crucible, and ignited; after which it may be weighed. From the weight of the sulphate thus obtained, that of the lead may be estimated, as follows:—

Atc. weight of sulphate of lead.		Atomic wt. of lead.		Weight of sulphate obtained.		Weight of lead in the quantity of the mixture employed.
152	.	104	::	a	:	x

CHAPTER V.

COPPER.

794. Like lead, copper is not often employed for the purpose of criminally destroying life; but is not unfrequently taken accidentally, dissolved in articles of food, with serious, and sometimes fatal results. The chief cause of such accidents is the employment of untinned copper vessels for culinary purposes; and although such vessels, when perfectly clean, may be used in the preparation of certain articles of food, without risk of impregnation, still the number of alimentary substances capable of acting upon and dissolving small quantities of the metal, is so great, that it is far safer to avoid the use of untinned copper vessels in all culinary operations. Acid and fatty substances especially, and liquids containing common salt and other saline matters in solution, should never be boiled in such vessels; since the quantity of copper dissolved by them is sometimes so considerable, as to impart a green or bluish colour to the mixture.

SECTION I.

Detection of Copper in Organic Mixtures.

795. Copper may exist in such mixtures either in a state of solution, or in combination with certain organic or other substances; forming compounds which are more or less insoluble in water. On this account, when the mixture to be examined consists of both liquid and solid matters, it should first be warmed with a little hydrochloric or acetic acid, by which means the copper will be brought into solution. The solution may then be filtered from the insoluble portion, which latter should be retained, in case it may be required for subsequent examination (798).

796. The clear liquid, slightly acidified with a few drops of hydrochloric acid, is now to be tested for copper, by placing in it a piece of clean iron, free from rust, such as a

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SECTION II.

Detection of Copper in the tissues.

799. Like the other metallic poisons, copper is readily absorbed by the tissues, where it may frequently be found in cases where no trace can be detected in the contents of the stomach and intestines. On this account, it is necessary, before concluding that no copper can be found, to examine the liver and other viscera, which may be done in the following manner.

800. The part intended for examination is to be cut into thin slices, and warmed with dilute nitric acid (consisting of one part of the strong acid and five or six parts of water), which will dissolve out any copper that may be present. The acid solution, after filtering, is evaporated nearly to dryness; after which it may be tested with a piece of clean iron (796), and, if necessary, with the other reagents mentioned in paragraph 797.

SECTION III.

Quantitative determination of Copper.

801. The quantity of copper present in any solution, or organic mixture, may be ascertained by saturating the liquid (after boiling with dilute acid, and filtering, if any solid or semi-solid matter is left undissolved), with hydrosulphuric acid gas, which will throw down the whole of the copper as sulphide. The precipitate is to be dissolved in hot nitric acid, and the copper thrown down as oxide, by supersaturating the hot solution of the nitrate with potash. The black oxide thus precipitated is to be washed with a large quantity of hot water, filtered, dried, ignited, and weighed. From the weight of the oxide, that of the metallic copper may be calculated as follows:—

Atc. wt. of oxide of copper.		Atc. wt. of copper.		Wt. of oxide obtained.		Wt. of copper in the quantity of mixture employed.
40	:	32	::	a	:	x

CHAPTER VI.

ZINC.

Detection of Zinc in organic mixtures and in the tissues.

802. Zinc has occasionally to be looked for in organic mixtures and in the tissues, the sulphate being often administered as an antidote in cases of poisoning. It may be detected by boiling the suspected matters in a finely divided state, with a little dilute hydrochloric acid, and filtering if necessary, from any insoluble residue. The clear solution thus obtained may then be supersaturated with ammonia, which will, at first, throw down a white gelatinous precipitate of hydrated oxide, which readily redissolves when the ammonia is added in excess. The mixture is then filtered; after which the clear ammoniacal solution may be tested with a current of hydrosulphuric acid gas (sulphuretted hydrogen), which, if zinc is present, will throw down a white precipitate of sulphide (ZnS). The sulphide thus formed may be separated from the liquid by filtration, and dissolved in a little hydrochloric acid or aqua regia; the excess of acid employed, being afterwards expelled by evaporating the solution to dryness.

803. A portion of the dry residue may be moistened with a solution of nitrate of cobalt, and heated on platinum wire before the blowpipe; when, if any zinc is present, the fused mass will exhibit a more or less decided green colour.

804. The remaining portion of the dry residue may then be dissolved in water, and the solution filtered from any sulphur that may be present; after which it may be tested for zinc as follows:—

(*a*) Hydrosulphate of ammonia gives a white precipitate of sulphide of zinc.

(*b*) Ammonia gives a white gelatinous precipitate of hydrated oxide, readily soluble in an excess of the precipitant.

(*c*) Ferrocyanide of potassium causes a white precipitate of ferrocyanide of zinc.

CHAPTER VII.

IODINE.

SECTION I.

Detection of uncombined Iodine in organic mixtures, &c.

805. When iodine is present in an organic mixture, it may be detected in the following manner; which will also serve to identify it after having been absorbed by the tissues of the stomach, liver, or other organ, such organ having been first carefully cut into thin slices, and macerated with a little water. The characteristic smell of iodine is generally perceptible in liquids containing it; and it usually imparts to organic mixtures a yellow or greenish colour.

806. The mixture may first be examined for any particles of iodine that may be present in the solid state; which, if found, may be at once identified as such, by the beautiful violet-coloured vapour which they form when gently heated in a small glass tube.

807. If no solid iodine can be found, the liquid may be tested with a solution of starch; or a strip of cotton or paper, impregnated with starch, may be moistened with it. If iodine is present in the solution, it will immediately strike a more or less decided purple colour, the intensity of the tint varying from almost black to a pale shade of pink or lilac, according to the quantity of iodine dissolved in the liquid.

808. Should the quantity of iodine in the solution be so minute as to fail in producing a sufficiently decided result, the mixture may be evaporated nearly to dryness on a water bath, and the residue digested with ether; which will dissolve, and carry with it to the surface, any iodine that may be present. The ethereal solution may then be evaporated at a gentle heat, and the residue examined for iodine by heating it gently in a small glass tube (806); or by dissolving it in water, and testing with starch (807).

SECTION II.

Detection of Iodide of Potassium (KI) in organic mixtures, &c.

809. If the organic mixture, or the liquid in which the sliced tissues have been macerated (805), is coloured to any considerable extent, it is advisable, before applying the tests, to remove the colouring matter by boiling with fresh animal charcoal; since the colour might interfere with, or mask, some of the results.

810. A little of the solution may then be mixed with a drop or two of nitric acid or a solution of chlorine, which, if any iodide is present, will decompose it, and set free the iodine (Prac. Chem. 435). The iodine thus liberated may then be detected by means of starch, in the manner already described (807).

811. The liquid suspected to contain iodide of potassium, may also be tested with solutions of acetate of lead and bichloride of mercury. With the first it will, if present, produce a bright yellow precipitate of iodide of lead; and with the second, a brilliant red precipitate of periodide of mercury.

CHAPTER VIII.

SULPHURIC ACID (HO,SO_3).

SECTION I.

Detection of Sulphuric Acid in organic mixtures.

812. Sulphuric acid may be readily detected, even when mixed with a large quantity of foreign matter. Should the substance to be examined be viscid or semi-solid, it may be diluted with a little water, and boiled; after which, if any solid matter remains in suspension, it may be filtered through muslin or paper.

813. If the liquid contains free sulphuric acid, it will of course strongly redden blue litmus paper.

814. Mix the liquid to be tested, with a little nitric acid, and add a solution of chloride of barium or nitrate of baryta. If sulphuric acid is present, a copious white precipitate of sulphate of baryta will be produced, which will not dissolve on boiling the acidified mixture, nor yet on diluting it with a considerable quantity of water (Prac. Chem. 445).

815. If no precipitate is occasioned by the baryta salt, it may be concluded that no sulphuric acid is present; but as certain other acids besides sulphuric might, if present, cause a similar precipitate, as, for instance, the sulphurous, iodic, or selenic, it is advisable to prove that the precipitate is really the sulphate, before finally deciding that sulphuric acid is present. The probability of any of the other acids which I have alluded to being contained in the liquid is, indeed, very small; but in all cases of medico-legal inquiry, no means should be neglected whereby the risk of error can be removed or diminished.

816. In order to prove whether the precipitate caused by the baryta salt is indeed the sulphate, it should be separated from the solution by filtration, dried, and mixed with four or five times its weight of pounded charcoal. The mixture is placed in a small tube closed at one end, and heated; when the sulphate will be converted into sulphide of barium (BaS), owing to the charcoal combining with the oxygen both of the baryta and the sulphuric acid. The ignited mixture, after cooling, is to be moistened with a few drops of dilute hydrochloric acid, which will disengage fumes of hydrosulphuric acid (sulphuretted hydrogen), readily detected by their offensive smell, and also by blackening a strip of paper moistened with a solution of lead, held at the open end of the tube.

817. Since traces of sulphuric acid may be contained in the nitric acid used in acidifying the mixture (814), a little of the nitric acid employed, should be diluted with three or four times its bulk of water, and tested with chloride of barium.

818. It is possible, also, that the substance under examination may contain some soluble sulphates in solution, as sulphate of magnesia, sulphate of zinc, &c., which would cause the precipitation of sulphate of baryta with chloride of barium, even when no free sulphuric acid is present. To remove this source of error, a little of the suspected fluid may be evaporated nearly to dryness at a gentle heat, when

any saline matter that may be present will crystallize out; while the free sulphuric acid will continue liquid, and may be identified by the proper tests. Or a little of the fluid, of known weight, may be evaporated and gently ignited, whereby the free acid will be expelled, while the sulphates will remain behind. Then, by estimating the amount of sulphuric acid in the saline residue (822), and ascertaining also by experiment the quantity of sulphuric acid in an equal weight of the fluid previous to evaporation, we can learn how much of the acid was in combination, and how much free; that in the ignited portion being derived from the sulphates, and the difference between the two representing the free acid which was expelled during ignition.

819. It is not often, however, that any serious uncertainty can exist as to whether the sulphuric acid found mixed with organic matter was or was not uncombined, especially in cases of suspected poisoning; since the corrosive effects of the acid upon the parts with which it has been in contact, or other corroborative circumstances, will generally of themselves furnish evidence sufficiently conclusive.

SECTION II.

Detection of Sulphuric Acid in stains on clothing.

820. The stains formed by sulphuric acid on articles of clothing are usually moist to the touch, and most commonly of a brown or red colour, varying, however, with the nature of the material and of the dye. The acid may be detected in them by boiling the stained part with water, and testing the solution with litmus paper (813), and with chloride of barium or nitrate of baryta (814).

SECTION III.

Detection of "Sulphate of Indigo" in organic mixtures, &c.

821. The solution of indigo in sulphuric acid, commonly called sulphate of indigo, which is occasionally either employed as a poison, or criminally thrown upon the person, may be detected in the same manner as the simple acid. It has a deep blue colour, which may be destroyed by

boiling with nitric acid previous to the application of the tests; after which the sulphuric acid may be identified either in organic mixtures or on articles of clothing, by the experiments described in paragraphs 814—818.

SECTION IV.

Quantitative determination of Sulphuric Acid.

822. The acid may, for this purpose, be precipitated in the form of sulphate of baryta, in the manner described in paragraph 814. The precipitate is then washed on a filter with boiling distilled water, dried, ignited, and weighed; when the quantity of acid may be calculated as follows:—

Atc. wt. of sulphate of baryta.		Atc. wt. of aqueous sulphuric acid.		Wt. of sulphate of baryta obtained.		Wt. of acid in the quantity of mixture employed.
117	:	49	::	a	:	x

CHAPTER IX.

HYDROCHLORIC ACID (*HCl*).

SECTION I.

Detection of Hydrochloric Acid in organic mixtures, &c.

823. When free hydrochloric acid is present in an organic mixture, it may be detected in the following manner. If solid or semi-solid matter is mixed with the liquid, it should be first boiled, and filtered through muslin; and when the mixture is thick and viscid, a little water should be mixed with it before boiling. The liquid is then treated with a tolerably strong infusion of galls, as long as it causes a precipitate, in order to throw down most of the dissolved animal matter, which would otherwise tend to prevent the acid distilling over. The precipitate is then separated from

the clear liquid, either by again filtering through muslin, or by decantation.

824. A few drops of the solution, thus purified from the greater portion of the organic matter, may now be tested with nitrate of silver. If this causes a white precipitate, soluble in ammonia, and insoluble in nitric acid, the liquid will have to be further examined (825); since the precipitate *may* be owing to the presence of chloride of sodium or some other soluble chloride. But if no such precipitate is occasioned by the silver salt, the absence of hydrochloric acid may be relied on; unless, indeed, the solution is ammoniacal, in which case it should first be neutralized or slightly supersaturated with nitric acid.

825. In order to prove whether the precipitate caused by nitrate of silver (824) is owing to the presence of free hydrochloric acid, or of some soluble chloride, the liquid is to be distilled to dryness in a retort. The neck of the retort is to be attached by means of a perforated cork to a quilled receiver, the quill of which should be allowed to dip just below the surface of a little pure water placed in the flask or bottle intended for its reception (Prac. Chem. 61). The bulb of the retort is to be heated in a chloride of calcium bath, the heat of which may be raised, towards the end of the distillation, to about 230°.

826. When the whole of the liquid has distilled over, the contents of the receiver are to be examined, first with blue litmus paper, which, if any free acid is present, will become reddened; and also with nitrate of silver, which will give a copious white precipitate of chloride, soluble in ammonia, and insoluble in nitric acid; in case any free hydrochloric acid was present in the mixture, since such acid would distil over with the water.

827. A little of the distilled liquid may also be mixed with a few drops of pure nitric acid, and boiled for a few minutes with a small fragment of gold leaf. If the latter dissolves, it is an additional proof that the acid is hydrochloric (Prac. Chem. 431).

828. In examining the contents of a stomach, it must be borne in mind that minute quantities of free hydrochloric acid are probably always present as one of the normal constituents of the gastric juice; so that the distilled liquid may always be expected to contain some traces of it. The amount of the acid derived from this source is, however, so

small, that it may readily be distinguished from the comparatively large quantity usually to be found when the acid has been swallowed.

SECTION II.

Quantitative determination of Hydrochloric Acid.

829. The chloride of silver (AgCl) obtained by adding nitrate of silver to the distilled acid liquid (826) is to be washed on a filter, dried, and heated to dull redness in a counterpoised porcelain crucible, until it begins to fuse. From the weight of the chloride thus obtained, that of the hydrochloric acid present in the mixture may be calculated as follows:—

Atc. weight of chloride of silver.		Atc. wt. of hydrochloric acid.		Wt. of chloride obtained.		Wt. of hydrochloric acid in the quantity of mixture employed.
144	:	37	::	a	:	x

CHAPTER X.

NITRIC ACID (NO_5).

SECTION I.

Detection of Nitric Acid in organic mixtures.

830. If any solid or semi-solid organic matter is present in the mixture, it should be separated by filtering through muslin, having first boiled it, in order to effect the separation of the greater part of the acid present, from the solid matters which may be more or less impregnated with it. Should the liquid be thick and viscid, it may be first diluted with a little water.

831. If free nitric acid is present in any considerable quantity in the liquid, it will probably be recognised by its peculiar smell; and the characteristic yellow stain of the tissues with which it has been in contact, is in most cases perceptible. The want of smell, however, is no proof

of the absence of the acid; which may still be present in considerable quantity, either diluted with a comparatively large amount of liquid, or even more or less completely neutralized by magnesia, or some other alkaline substance that may have been administered as an antidote. In the latter case, the liquid may be neutral, or nearly so, to test paper.

832. In order to detect nitric acid, the liquid, after filtration (830), may, if acid, be neutralized with carbonate of potash, and evaporated to dryness at a gentle heat. The nitric acid will thus be obtained in combination with potash, forming nitrate of potash, which will be deposited in needle-shaped crystals when most of the water is expelled; unless, indeed, the crystallization is prevented by the admixture of much animal or other matters.

833. The greater part of the saline residue thus obtained, is to be dissolved in as small a quantity of water as possible, and the solution placed in four test tubes, for the following experiments:—

(*a*) The first portion is mixed in a small test tube, with a few drops of strong sulphuric acid; after which a clean strip or two of copper, or a little roll of copper wire, is dropped in, and, if necessary, a gentle heat applied. If nitric acid is present, orange fumes of nitrous acid will be given off, the smell of which may generally be recognised, even when in too small quantity to be apparent to the eye.

(*b*) To the second portion add a few drops of hydrochloric acid, and put a small fragment or two of gold leaf into the mixture. If nitric acid is present, the gold leaf will be partially or wholly dissolved; and the presence of gold in the solution, may be proved by protochloride of tin causing with it a purple precipitate.

(*c*) The third portion is to be acidified with a few drops of strong sulphuric acid, and as soon as the mixture is cool, a small crystal of protosulphate of iron is dropped in; when, if nitric acid is present, the liquid round the crystal will assume a brown colour, which disappears on boiling the mixture.

(*d*) Mix the remaining portion of the solution with sulphuric acid, and add a drop of dilute sulphate of indigo, sufficient to give the liquid a pale blue colour. If nitric acid is present, the colour of the indigo will disappear, especially on warming the mixture.

SECTION II.

Detection of Nitric Acid in stains on clothing.

834. Stains occasioned by the action of nitric acid on woollen cloth are usually of a brown or yellowish colour, and, unlike those caused by sulphuric acid (820), become in a short time dry and extremely rotten. If recent, the acid may generally be detected in them, by boiling the stained part with a little water, neutralizing with potash, and applying the tests mentioned in paragraph 833; but if any considerable time has elapsed since the production of the stain, it is probable that all traces of the acid will have disappeared, partly by evaporation, and partly by decomposition occasioned by contact with the organic matter.

CHAPTER XI.

OXALIC ACID (HO,C_2O_3).

SECTION I.

Detection of Oxalic Acid in organic mixtures.

835. Before proceeding to apply the several tests for oxalic acid, in the contents of a stomach, vomited matters, or other mixtures containing organic matter, it is advisable first to separate the latter, since its presence might interfere with the action of some of the reagents. If lime or magnesia has been used as an antidote, the oxalic acid, if present, will be either wholly or in part in the form of an insoluble oxalate; so that, in that case, it is necessary to boil the sediment with a solution of carbonate of potash, whereby the acid will be brought into solution as oxalate of potash (KO,C_2O_3); an insoluble carbonate of the earth being at the same time formed.

$$CaO,C_2O_3+KO,CO_2=KO,C_2O_3+CaO,CO_2.$$

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SECTION II.

Quantitative determination of Oxalic Acid.

838. The quantity of oxalic acid in the liquid may be estimated in the following manner. The solution is first acidified with a little nitric acid, in order to decompose any soluble carbonate that may be present; after which it may be neutralized with ammonia. A solution of chloride of calcium is now to be added as long as it causes any precipitate; and the mixture is boiled and filtered. The precipitate, after being washed on the filter, is dried, and gently ignited in a counterpoised crucible. It is then, after cooling, moistened with a solution of carbonate of ammonia, and again heated a little below redness, in order to expel the excess of the ammoniacal salt, which was added for the purpose of supplying carbonic acid to any lime that may have been rendered caustic during the first ignition (837 *b*).

839. The oxalate of lime is thus wholly converted into carbonate; which is to be weighed, and from its weight that of the oxalic acid may be calculated as follows:—

Atc. wt. of carbonate of lime.		Atc. wt. of crystallized oxalic acid.		Wt. of carb. lime obtained.		Wt. of oxalic acid in the quantity of liquid employed.
50	:	63	::	a	:	x

CHAPTER XII.

HYDROCYANIC (OR PRUSSIC) ACID (*HCy*).

840. The presence of hydrocyanic acid, even when largely diluted, may usually be detected by its peculiar and characteristic odour, somewhat resembling that of oil of bitter almonds. Great caution is necessary not to inhale more than the smallest quantity of the vapour, since headache and other unpleasant symptoms may be occasioned by merely smelling it, even when in a highly diluted state.

841. It must be remembered, in cases of suspected poisoning with this acid, that no time should be lost in applying the tests for its presence; since it rapidly volatilizes, and unless carefully protected from the air, disappears entirely in the course of a few days.

SECTION I.

Detection of Hydrocyanic Acid in organic mixtures.

I. *Detection of the acid in the state of vapour.*

842. Very small traces of the acid may be detected by one or other of the following tests, which may be readily applied to any liquid or mixture suspected to contain it. There is also this advantage in being able to identify it without going through the process of distillation at a higher temperature—viz., that while the tests for the vapour which I am about to describe, are equally, or even more delicate than those for the liquid after distillation (846), the possibility, however remote, of the spontaneous formation of the acid by the decomposition of the organic matter during distillation, is altogether prevented.

843. A little of the mixture suspected to contain the poison may be placed in a watch glass, over which another similar watch glass is to be inverted, having been previously moistened with a drop or two of a solution of nitrate of silver, care being taken that none of the latter is allowed to run into the lower glass. The glass containing the suspected solution is then very gently warmed by holding it in the hand; when, if any hydrocyanic acid is present, it will volatilize into the upper glass; where, on coming in contact with the silver solution, it will form a white film of cyanide of silver (AgCy). This test is very delicate; but as a somewhat similar effect might be produced by hydrochloric acid, it is always advisable to confirm the result by the following experiments.

844. A little of the suspected mixture is put into a watch glass, over which is placed another glass moistened with a drop or two of solution of potash. The hydrocyanic acid, if present, gradually evaporates into the upper glass, where it combines with the potash, forming in solution a little cyanide of potassium. This is then mixed, first with a drop of a solution of protosulphate of iron (which should have been exposed to the air for a short time, so as to have become partially converted into the persulphate), and afterwards with a drop or two of dilute hydrochloric acid, which should be added in slight excess. Should any hydrocyanic acid have been present in the mixture, a blue precipitate of Prussian blue will be immediately formed, the

appearance of which may be considered as a sure proof of the existence of the acid. This experiment is commonly known as *Scheele's*, or the *iron test*.

845. The following test, commonly known as the *sulphur test*, which is perhaps the most delicate of all, may also be applied. A little of the suspected fluid is put into a watch glass as before, and over this, another watch glass is inverted, containing a drop of hydrosulphate of ammonia, which for this purpose should contain an excess of sulphur, and consequently have a yellow colour. The glasses may be allowed to remain together for about a quarter or half an hour; after which the upper one is removed, and placed on a water bath, until the hydrosulphate of ammonia is evaporated to dryness. Should any hydrocyanic acid have been present in the liquid, some of its vapour will have mixed with the hydrosulphate, with which it would form sulphocyanate of ammonia. The residue left after the evaporation of the drop, is now to be moistened with a dilute solution of persulphate of iron; which, in case any sulphocyanate of ammonia had been formed, or, in other words, in case any hydrocyanic acid had been present in the suspected mixture, will immediately produce a blood-red colour, owing to the formation of sulphocyanide of iron.

II. *Detection of Hydrocyanic Acid in solution.*

846. The mixture suspected to contain the poison, is to be distilled in a retort heated on a water bath, the receiver being kept cool by immersion in cold water, or in a freezing mixture composed of ice and salt, or of equal weights of nitrate of ammonia and water (Prac. Chem. 61). When about one-eighth part of the liquid has passed over into the receiver, the distillation may be stopped. Should the mixture, previous to distillation, be at all alkaline to test paper, it should be slightly acidified with dilute sulphuric acid, in order to disengage the hydrocyanic acid from the ammonia, or other bases which may be present, and which would prevent the distillation of the acid at the low temperature employed. The presence of hydrocyanic acid in the distilled liquid may be ascertained by the following peculiarities :—

847. Unless the quantity of acid be very minute, the peculiar odour, resembling that of oil of bitter almonds, will probably be apparent.

848. Test a little of the distilled liquid with a solution of nitrate of silver. If hydrocyanic acid is present, a white precipitate of cyanide of silver is produced, which is soluble in ammonia and in hot nitric acid, but insoluble in the cold acid. When treated with hydrochloric acid, the precipitate gives off hydrocyanic acid vapour, which may be recognised by its odour (840), and chloride of silver is at the same time formed.

849. Add to a little of the distilled liquid in a test tube, first, a little solution of potash; then a drop or two of a solution of protosulphate of iron, containing also a little persulphate (844); and lastly, a slight excess of dilute hydrochloric acid. If the liquid contains hydrocyanic acid, a precipitate of Prussian blue will be immediately produced; or if only a small trace is present, a few hours may elapse before it becomes apparent.

850. Mix another portion of the distilled liquid with a few drops of yellow hydrosulphate of ammonia (845), and evaporate the mixture to dryness on a water bath. On moistening the dry residue with a solution of persulphate of iron, a blood-red colour of sulphocyanide of iron will be produced, in case any traces of hydrocyanic acid are present. The colour of the sulphocyanide of iron is immediately destroyed on the addition of a drop or two of a solution of bichloride of mercury; in which respect it differs from that caused on mixing a persalt of iron with a solution of meconic acid (863).

851. The evaporation to dryness in this experiment is necessary, in order to decompose the excess of hydrosulphate of ammonia; which would otherwise form with the iron solution a black precipitate of sulphide, and thus obscure the appearance of the characteristic red colour. During the evaporation, the heat must be kept very moderate, lest any of the sulphocyanate of ammonia that may be formed by the action of the hydrocyanic acid on the hydrosulphate, should be decomposed.

852. Should no decided indication of the acid be afforded by these tests, a little of the distilled liquid may be examined in the manner described in paragraphs 843—845.

SECTION II.

Quantitative determination of Hydrocyanic Acid.

853. The quantity of hydrocyanic acid contained in an organic mixture may be ascertained with sufficient accuracy for most purposes, by distilling the acid (846), and precipitating the distilled liquid by means of nitrate of silver. The precipitated cyanide of silver is washed and dried in a hot water oven until it ceases to lose weight. From the weight of the cyanide thus obtained, that of the anhydrous hydrocyanic acid (HCy) may be calculated as follows:—

Atc. wt. of cyanide of silver.		Atc. wt. of hydrocyanic acid.		Wt. of cyanide of silver obtained.		Wt. of hydrocyanic acid in the quantity of mixture employed.
134	:	27	::	a	:	x

CHAPTER XIII.

OPIUM.

854. Of the several compounds contained in, and peculiar to opium, two only, morphia ($C_{35}H_{20}NO_6$) and meconic acid ($3HO,C_{14}HO_{11}$), are possessed of sufficiently characteristic properties to enable us to identify them when mixed with other matters; the tests for these substances, moreover, are not particularly delicate, so that it is difficult, and not unfrequently impossible, to detect small traces of them. In cases of poisoning with opium, it is seldom that any traces of it can be found in the contents of the stomach; so that the tissues of the stomach itself, the intestines, and also any vomited matters, ought to be carefully examined for the poison.

Detection of Opium in organic mixtures, tissues, &c.

855. If the substance to be examined is liquid, or semi-fluid, it should first be evaporated to dryness, or nearly so,

on a water bath. If solid, the suspected substance may be cut into thin slices. The residue left after evaporation, or the sliced solid matter, as the case may be, is then to be digested for an hour or two, with the aid of a gentle heat, in a flask placed on a water bath, with a small quantity of water containing a little acetic acid. The mixture is filtered, and the clear liquid, containing a slight excess of acetic acid, is treated with a solution of acetate of lead ($PbO,C_4H_3O_3+3Aq$) as long as any precipitate is produced. The meconic acid, if present, is thus thrown down in combination with oxide of lead, forming meconate of lead ($3PbO,C_{14}HO_{11}$); while the morphia remains in solution in combination with acetic acid (acetate of morphia ($C_{35}H_{20}NO_6,C_4H_3O_3$),) together with any excess of acetate of lead that may have been employed. The mixture is warmed (not boiled, since by boiling, some of the meconic acid might become decomposed), and when again cold, is filtered.

856. The clear solution may first be examined for morphia; reserving the precipitate for subsequent examination (862).

857. A current of hydrosulphuric acid (sulphuretted hydrogen) is passed through the solution, until the latter smells distinctly of the gas, in order to decompose the excess of acetate of lead. The precipitated sulphide of lead is separated by filtration from the solution; which latter, after boiling, and if necessary concentrating by evaporation, is to be examined for morphia by means of the following tests:—

858. Place a drop or two of the concentrated solution on a strip of glass, and add a drop of ammonia. The morphia will be precipitated in the form of minute needle-shaped crystals, which may be examined under the microscope.

859. Another small portion of the solution is mixed with a solution of iodic acid (IO_5); if morphia is present, the iodic acid will be deoxidized, and the reduced iodine will give the liquid a brown or yellowish tint. If now a little solution of starch be added, it will cause a purple precipitate of iodide of starch.

860. Nitric acid forms with tolerably strong solutions of morphia, an orange-yellow coloured compound, which becomes lighter in colour when boiled.

861. A solution of perchloride of iron causes in neutral

solutions containing morphia, a bluish inky-coloured precipitate, somewhat similar to that caused in an infusion of galls. If the mixture be treated with nitric acid, the blue colour disappears, and the orange-yellow compound is formed (860).

862. The precipitate, supposed to contain meconate of lead (856), is now to be mixed with water in a beaker glass; and while suspended in the liquid, treated with a current of hydrosulphuric acid, the mixture being stirred occasionally. The meconate of lead is thus decomposed; the black sulphide of lead being precipitated, while the meconic acid, if present, remains in solution. The mixture is filtered to separate the sulphide of lead, and the clear liquid is gently warmed (not boiled (855),) in order to expel the excess of hydrosulphuric acid; and, if necessary, concentrated by evaporation on a water bath. The meconic acid, if present in sufficient quantity, may then be detected by the following tests :—

863. A solution of perchloride of iron gives the liquid, in case meconic acid is present, a bright red colour, owing to the formation of meconate of iron. The colour closely resembles that caused in solutions of iron by the sulphocyanides, from which it may be distinguished by not being decolorized by a solution of bichloride of mercury (850). It is, however, destroyed by boiling nitric acid, chloride of tin, and the caustic alkalies.

864. Solutions of acetate of lead, chloride of barium, and nitrate of silver, produce white precipitates of meconates, which are all soluble in an excess of nitric acid.

865. Ammoniosulphate of copper throws down a green precipitate of meconate of copper, which is soluble in nitric and hydrochloric acids.

CHAPTER XIV.

METHOD OF EXAMINING AN ORGANIC MIXTURE, SUSPECTED TO CONTAIN SOME MINERAL POISON, THE NATURE OF WHICH IS UNKNOWN—VIZ., ARSENIC, ANTIMONY, MERCURY, LEAD, OR COPPER.

866. When an organic mixture is suspected to contain one of the above-mentioned mineral poisons, it may be examined in the following manner. If the matter to be examined is solid, it should first be cut into thin slices, and any lumps of solid or semi-solid matter that may be present should be crushed and disintegrated. About three-fourths of the mixture may then be treated with hydrochloric acid, as already described in the case of arsenic (757, &c.), and gently boiled; the remaining fourth part being retained, in case it may be required for further examination. If anything remains undissolved after the digestion with acid, it may be separated by filtering through muslin, and retained for subsequent testing, in case the examination of the liquid portion should prove unsuccessful (871). The greater part of the excess of hydrochloric acid may then be expelled by evaporation on a water bath; after which it may be tested in the following manner.

867. A little of the solution may first be tried with Marsh's test, in the manner described in paragraphs 745—748, whereby any ARSENIC or ANTIMONY that may be present will readily be detected. (Confirm, for arsenic, 749, 742—744; for antimony, 764, 765).

868. Try another portion of the solution for MERCURY with Reinsch's test, in the manner described in paragraphs 770, &c. (Confirm, 773).

869. Another portion of the clear liquid may be tested with a drop or two of dilute sulphuric acid, or a solution of sulphate of soda. If any LEAD is present, it will cause a white precipitate; which, after being washed, is turned black when moistened with hydrosulphate of ammonia (786 *b* & *c*.) (Confirm, 786, *d*, *e*, *f*).

870. If COPPER is present in the solution, it may be detected by immersing a needle or other piece of clean iron, which will in that case become covered with a coating of metallic copper (796); or by adding a slight excess of ammonia, which will cause the liquid to assume a more or less intense blue colour (797 *b*). (Confirm, 797, *c* & *d*).

871. In case no poison can be detected in the solution, the solid portion which was separated by filtration may be boiled with tolerably strong nitric acid, in order to ensure the solution of any traces of the metals that may be contained in it. The acid mixture is then diluted with a little water, filtered if necessary, and deprived of the greater part of the excess of acid by evaporation on a water bath; after which it may be tested for the several metals in the manner above described (867 &c).

APPENDIX.

WEIGHTS AND MEASURES.

Troy or Apothecaries' Weight.

Pound.		Ounces.		Drachms.		Scruples.		Grains.		French Grammes.
1	=	12	=	96	=	288	=	5760	=	372.96
		1	=	8	=	24	=	480	=	31.08
				1	=	3	=	60	=	3.885
						1	=	20	=	1.295
								1	=	0.0647

Avoirdupois Weight.

Pound.		Ounces.		Drachms.		Grains.		French Grammes.
1	=	16	=	256	=	7000	=	453.25
		1	=	16	=	437.5	=	28.328
				1	=	27.343	=	1.77

Imperial Measure.

Gallon.		Pints.		Fluidounces.		Fluidrachms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

Weight of Water at 62°, contained in the Imperial Gallon, &c.

			Grains.
1	Imperial Gallon	=	70,000
1	,, Pint	=	8750
1	,, Fluid Ounce	=	437.5
1	,, Fluid Drachm	=	54.7
1	,, Minim	=	0.91

Cubic Inches contained in the Imperial Gallon, &c.

		Cubic Inches.
1 Imperial Gallon	=	277.273
1 ,, Pint	=	34.659
1 ,, Fluid Ounce	=	1.732
1 ,, Fluid Drachm	=	0.2166
1 ,, Minim	=	0.0036

FRENCH WEIGHTS AND MEASURES.

Measures of Length.

		English Inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100						
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Kilometre	=	39371.00000	=	0	4	213	1	10.2
Myriometre	=	393710.00000	=	6	1	156	0	6

Measures of Capacity.

		Cubic Inches.		English Imperial Measure. Gall.	Pints.	F.oz.	F.drms.	Min.
Millilitre	=	.06102	=	0	0	0	0	16.3
Centilitre	=	.61028	=	0	0	0	2	42
Decilitre	=	6.10280	=	0	0	3	3	2
Litre	=	61.02800	=	0	1	15	1	43
Decalitre	=	610.28000	=	2	1	12	1	16
Hecatolitre	=	6102.80000	=	22	0	1	4	48
Kilolitre	=	61028.00000	=	220	0	12	6	24
Myriolitre	=	610280.00000	=	2200	7	13	4	48

Measures of Weight.

		English Grains.		*Avoirdupois.* Poun.	Oun.	Dram.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444				
Gramme	=	15.4440				
Decagramme	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Kilogramme	=	15444.0234	=	2	3	5
Myriogramme	=	154440.2344	=	22	1	2

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