A practical manual : containing a description of the general, chemical and microscopical characters of the blood, and secretions of the human body, as well as of their components, including both their healthy and diseased states ... / by John William Griffith.

GRIFFITH
ON
THE BLOOD
&c.

A PRACTICAL MANUAL,

CONTAINING A

DESCRIPTION OF THE GENERAL, CHEMICAL AND MICROSCOPICAL

CHARACTERS OF THE BLOOD,

AND

SECRETIONS OF THE HUMAN BODY,

AS WELL AS OF THEIR COMPONENTS,

INCLUDING BOTH THEIR HEALTHY AND DISEASED STATES; WITH THE BEST METHODS OF SEPARATING AND ESTIMATING THEIR INGREDIENTS;

ALSO,

A SUCCINCT ACCOUNT OF THE VARIOUS CONCRETIONS OCCASIONALLY FOUND IN THE BODY AND FORMING CALCULI.

BY

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PREFACE TO PART II.

THIS Part forms the completion of the work. The properties of the substances entering into the composition of the various animal fluids are here entered into rather more fully than in the preceding Part, and their leading characteristics detailed. The results of the numerous analyses which have been made are but rarely noticed, my object being rather to show the manner in which such may be best made. The excellent work of Simon will however be found to supply this deficiency, for in the second volume the most important results which have been obtained in this branch of investigation are contained; and as a translation of it has been issued by the Sydenham Society, it is within the reach

of all who are interested in the subject. Organic or ultimate analysis is not treated of, although it is frequently indispensable in the investigation of the nature of animal matters. This was expressly avoided, since distinct treatises have been published on it; and it is moreover usually considered to require too much time and too minute a knowledge of chemical manipulation to come within the grasp of the medical practitioner.

An Appendix is added, into which any discoveries or new processes of importance that have appeared since the publication of the first Part, and which come within the limits of the Manual, are abstracted.

It would be mere waste of time to attempt to detail the advantages to be derived from a more extended examination of the properties of the components of the human body in its normal state of health, and in its deviations from this condition. The important light which has been thrown upon several points in physiology and pathology by the researches of modern chemistry and microscopy are so striking, that to be alone acquainted with them is sufficient to ensure a due appreciation of their importance.

To argue that such investigations are idle, merely because each new truth which is elicited is not immediately applicable to the elucidation of some point in the history of a disease, or to the improved application of remedial means for its alleviation, is as absurd as unfortunately it is frequent. There is however one consolation in this matter, which is, that those who are the most ready to urge these views and to decry the utility of calling in the aid of the collateral sciences, are such as are least acquainted with their details.

In conclusion, if by writing this little book I may at all contribute to excite an increased taste for the cultivation of the subjects of which it treats, I shall feel amply repaid for any trouble bestowed upon it.

9 St. John's Square,
April 1846.

CORRIGENDA.

Part I.

Page 39, *note*, *line* 2, *dele* as well as gelatine.
... 52, *line* 30, *after* it is *insert* not.
... 52, ... 33, *for* this is not *read* this is.
... 53, ... 13, expresses the composition of xanthic oxide.

Part II.

Page 77, *line* 26, *for* these *read* the two latter.
... 77. The last five lines should read thus:—The weight of the dried fibrine and of the solids of the serum corresponding to the amount of serum contained in the clot is then deducted from the weight of the dried clot; the difference gives the weight of the corpuscles. The amount of solid matter corresponding to the serum contained in the clot is thus ascertained:—A quantity of solid matter is calculated for the amount of water, &c.

PART II.

CONTAINING THE

GENERAL, CHEMICAL AND MICROSCOPICAL

CHARACTERS OF THE BLOOD,

ETC.,

BOTH IN HEALTH AND DISEASE.

GENERAL, CHEMICAL

AND

MICROSCOPICAL CHARACTERS

OF THE BLOOD, &c.

BEFORE treating of the characters of the compound fluids, those proximate principles, &c. which are generally diffused through them will be described; those which are found in peculiar fluids only will be treated of with the fluids themselves.

I. PROTEINE COMPOUNDS.

These substances consist of combinations of an organic principle with sulphur and phosphorus in various proportions; the organic principle itself is called proteine. They exist in two states, a fluid and a solid. In the former they are coagulated by electricity; and after the addition of acetic acid, by solution of ferrocyanide of potassium. When in the coagulated or solid state, they are insoluble in water, alcohol and æther, partly soluble in acetic acid, en-

tirely so in alkalies by heat, and on the addition of acetic acid to the alkaline solution the proteine is precipitated. When boiled with muriatic acid they gradually dissolve, assuming a lilac or bluish-purple tinge. When boiled with water, the base becomes oxidized.

1. PROTEINE does not occur in the solids or fluids of the body in an uncombined state.

Chemical properties.—a. When carefully dried, it forms a brownish amber-coloured mass, which is hard, brittle, and may be readily pulverized; it absorbs moisture from the air, but may be completely dried at 212° F.; when immersed in water, this is absorbed, rendering the proteine gelatinous, and forming semi-transparent flakes. It is insoluble in water, alcohol and æther. When heated, it does not fuse until decomposition commences; it then swells up and evolves the ordinary products of decomposition of nitrogenous bodies. It leaves no ash. By long-continued ebullition with water, it does not yield gelatine, but two substances which have been only recently discovered by the indefatigable Mulder. Proteine combines with acids and bases. It dissolves in acetic acid, and the solution is precipitated by ferrocyanide of potassium*; it is soluble in very dilute, but precipitated by strong acids†, except the acetic and phosphoric; tannic acid and potash likewise precipitate it from its solutions in acids. On ebullition with dilute sulphuric acid, it becomes coloured purplish-

* This precipitate is composed of hydrocyanic acid, proteine and cyanide of iron.

† These are compounds of the acid with proteine.

red; with nitric acid, yellow or orange; with muriatic, at first yellowish, then bluish-purple, and ultimately brownish or black. The presence of oxygen is requisite for the production of this change in colour, which is a very characteristic phænomenon. Proteine dissolves in alkalies without change; the resulting compounds are insoluble in alcohol. When boiled with excess of potash, carbonate and formiate of ammonia, leucine, protide and erythroprotide are formed.

Proteine is composed per cent. of carbon, 55·22; hydrogen, 6·99; nitrogen, 15·97; and oxygen, 21·82, giving the formula $C^{40}\ H^{30}\ N^{5}\ O^{12}$*. Its atomic weight is 436.

b. Proteine may be obtained by treating fibrine, albumen, caseine, or any substance containing it, with water, alcohol, æther and dilute muriatic acid† in succession. It is then heated for some time to 120° in a moderately strong solution of caustic potash‡. Acetic acid is then added in the slightest possible excess; the precipitate is collected on a filter and washed with distilled water.

c. Proteine forms two oxides:—

a. The binoxide is left in an insoluble form after fibrine has been boiled with water for some hours; it is purified by ebullition with alcohol and æther, in which it is insoluble. It is soluble in the dilute mineral and acetic acids; ferrocyanide of potassium precipitates it from the acid solution; it is also

* Liebig assumes the formula $C^{48}\ H^{36}\ N^{6}\ O^{14}$.

† These agents remove extractives, fat, salts, &c.

‡ This removes the sulphur and phosphorus, forming sulphuret of potassium and phosphate of potash.

soluble in solution of potash and ammonia, and does not assume so deep a yellow colour from the action of nitric acid as proteine.

It is composed of 1 atom of proteine + 2 atoms of oxygen, yielding carbon, 53·52; hydrogen, 7·17; nitrogen, 14·80; oxygen, 24·51 = $C^{40} H^{30} N^{5} O^{14}$.

β. The tritoxide is formed by boiling fibrine or albumen in water for many hours, precipitating by acetate of lead, and neutralizing the solution with ammonia. The precipitates are collected on a filter, and the lead separated by sulphuretted hydrogen; on evaporating the solution, the tritoxide remains. It is soluble in both hot and cold water and in alkalies, but is almost insoluble in alcohol and quite so in æther. It is precipitated by the mineral acids, bichloride of mercury, and both acetates of lead, but not by ferrocyanide of potassium.

It is composed of 1 atom of proteine + 3 atoms of oxygen, yielding carbon, 51·38; hydrogen, 6·78; nitrogen, 15·01; oxygen, 26·82.

d. With sulphuric acid, proteine forms a gelatinous compound, consisting of 1 atom of each constituent; it is called sulpho-proteic acid. When dry, it is yellow, insoluble in water, alcohol and æther, and forms compounds with metallic oxides.

When a solution of proteine (albumen or caseine) in acetic acid is dropped into very dilute sulphuric acid, a flocculent precipitate of subsulphate of proteine is formed; it contains 2 atoms of proteine to 1 of acid.

e. When acted upon by nitric acid, a yellow substance, xantho-proteic acid, remains undissolved,

whilst nitrate of ammonia, oxalic and saccharic acids are formed in the solution. It is composed of $C^{34} H^{24} N^4 O^{12} + HO$, and is insoluble in water, alcohol and æther.

f. Proteine also forms compounds with alkalies and metallic oxides.

g. When chlorine is passed through a solution of proteine, proteo-chlorous acid is precipitated in the form of white flakes; it consists of $C^{40} H^{30} N^5 O^{12} + ClO^3$, and is dissolved by solution of ammonia.

h. Protide is of a yellow colour, soluble in water and cold alcohol, but precipitated from its solution by basic acetate of lead, not by other metallic salts or tannic acid. Its composition is $C^{13} H^9 N O^4$.

i. Erythroprotide subsides from its alcoholic solution on cooling, is of a reddish colour, readily soluble in water and hot alcohol, and is precipitated by salts of lead and silver. Its composition is $C^{13} H^8 N O^5$.

k. There is no peculiarity in the microscopic appearance of proteine.

2. Albumen.—Some observations relating especially to the detection of albumen were made in Part I. p. 38.

Chem. prop.—*a. Fluid.*—In this form it is coagulated at 158° F., the temperature requiring to be more elevated as the amount of albumen in solution is less; free alkali or acid prevents its occurrence. Albumen is precipitated by the concentrated mineral acids*, alcohol, lactic acid, bichloride of mer-

* Phosphoric acid does not cause a precipitate, but metaphosphoric acid does.

cury *, nitrate of silver, both acetates of lead †, alum, protosulphate of iron, chloride of tin ‡ and tannic acid. Chromic acid causes a precipitate in a very dilute solution. Copious dilution with water also causes a precipitation of part of the albumen.

β. Coagulated.—In this state when dried it forms yellowish brittle masses, which when pulverized in a warm mortar become powerfully electrical, adhering strongly to the pestle; in cold water it swells, and a very small portion appears to dissolve §. It is insoluble in alcohol and æther, and is incinerated with difficulty, leaving an ash containing phosphate of lime. It swells into a jelly in acetic acid, and is finally soluble in water, especially when heated. Sulphuric and nitric acids behave to it as to proteine. It completely neutralizes alkalies. The quantity of ash left on incineration varies from 1·3 to 11 per cent. In addition to the principal constituent, phosphate of lime, it also contains a trace of phosphate of magnesia with chloride of sodium and carbonate of soda.

It is composed of carbon, 54·84; hydrogen, 7·09;

* This is composed of albuminate of mercury, muriate of albumen remaining in solution. The latter may be removed by washing with water.

† Neutral acetate of lead throws down a part only of the albumen, the diacetate the whole. In the former case, some of the albumen combines with, and is retained in solution by, the acetic acid; in the latter, the whole of the albumen combines with the excess of oxide of lead, neutral acetate of lead remaining in solution. Excess of the diacetate redissolves the precipitate.

‡ Excess redissolves the precipitate.

§ 7 parts in 1000 (Chevreul).

nitrogen, 15·83; oxygen, 21·23; phosphorus, 0·33; and sulphur, 0·68; or proteine, 10 atoms + S^2, P*.

γ. Albumen enters into combination with acids and alkalies. When solutions of metallic salts are added to it, a compound of the acid and albumen remains in solution, and may be washed away, whilst the metallic oxide combined with another portion remains insoluble. It was formerly supposed that albumen is dissolved in animal fluids by the free or carbonated soda and salts always existing in them; the experiments of Wurtz have however shown that this is not the case, at least in some instances.

δ. To separate pure albumen, add muriatic acid to an albuminous solution until no further precipitate is occasioned, wash away the supernatant liquid with very dilute muriatic acid, dissolve the precipitate in cold water, and throw down the albumen with carbonate of ammonia, collect it on a filter, wash, dry and separate all fat by boiling alcohol and æther; or boil an albuminous liquid, taking care that any free alkali is neutralized, filter, wash and dry the precipitate, then digest it in dilute muriatic acid, and subsequently treat it with alcohol and æther. In quantitative analysis it may be estimated as the insoluble residue of the digestion of water, æther and alcohol on the dried extract, separation from the earthy phosphates, &c. being effected by incineration.

ε. Albumen, when long boiled with water, yields tritoxide of proteine, a portion of unaltered albumen

* The albumen of eggs contains a single atom only of sulphur, thus agreeing with fibrine in composition.

remaining undissolved. It thus differs from fibrine in the tritoxide being formed at once, without the intervention of the binoxide.

If an albuminous solution be heated in an atmosphere of oxygen, a scum is formed on its surface.

Microscopical characters.—See Part I. p. 40.

3. Globuline.—This substance, which occurs in the blood and crystalline lens, is undoubtedly a proteine compound, resembling albumen very closely in its properties.

Chem. prop.—α. It is precipitated from its solution by alcohol; the precipitate is insoluble in water, but is partly soluble in boiling weak alcohol, partly separating as the solution cools. It is precipitated from its solution in an alkali by acetic acid, but not from the blood, when freed as perfectly as possible from albumen. A scum forms upon its surface on ebullition.

When solid, it is but little acted upon by alcohol; acetic acid with heat partly dissolves it. In most other respects it agrees with albumen in its properties*. It is insoluble in alcohol acidified with sulphuric acid. According to Mulder's analysis, it is composed of 15 atoms of proteine + S†.

β. It may be obtained by decomposing the sulphate with finely powdered marble, then dissolving the substance in boiling spirit (0·915); on cooling it subsides.

* For some further observations on this substance, see 'Medical Gazette,' vol. xxxvi. p. 184.

† Mulder found the per-centage of sulphur = 0·272.

4. FIBRINE, like albumen, exists in two states, a fluid and a solid.

a. Fluid.—We have but little opportunity of examining fibrine in its naturally fluid state, for as soon as it is removed from the living vessels it commences to solidify. The addition of salts, as sulphate or carbonate of soda, &c., will however prevent this. It is perhaps beyond the limits of this manual to enter into the question, whether the fibrine is really dissolved in the blood and other fluids, or whether it exists in a semi-fluid state or suspended in the form of minute particles, the cohering of which causes the apparent coagulation. I have no doubt that the former view is correct; for although minute granules can always be detected in fibrinous and other animal fluids, if a drop of the latter be placed under the microscope prior to coagulation, the fibres or masses of fibrine which are subsequently seen to form are far more considerable than could possibly have resulted from the union of the scattered granules.

β. Solid.—In this state, fibrine is almost entirely insoluble in water, alcohol and æther. When dried and free from fat, it forms a yellowish opake mass; if at all transparent, it still contains fat. It is difficultly incinerated, leaving an ash consisting of about 0·6–0·8 per cent.; this is composed of phosphate of lime, a little phosphate of magnesia, and sometimes a little silica; but it contains neither iron, alkali, nor carbonate of lime. Muriatic acid with heat colours it of an indigo-blue colour. It is much more readily acted upon by acetic acid than albumen. It becomes yellow with nitric acid. Alkalies saturate it as per-

fectly as albumen. Peroxide of hydrogen added to moist fibrine is decomposed, oxygen being evolved and water formed; this does not occur however if the fibrine has been boiled with water or digested with alcohol; it also happens, in a greater or less degree, with many organic tissues which contain no fibrine. Notwithstanding the similarity between the two, it does not occur with albumen*. Fibrine usually contains about 2–4 per cent. of fat.

It is composed of 10 atoms of proteine S + P, yielding carbon, 54·56; hydrogen, 6·90; nitrogen, 15·72; oxygen, 22·13; sulphur, 0·36; and phosphorus, 0·33 per cent.

When boiled it is first transformed into binoxide, and subsequently into tritoxide of proteine.

γ. Fibrine is most readily obtained by stirring blood immediately after its withdrawal from a vessel with a glass rod; the clot is thoroughly washed with water, being occasionally pressed until it is completely colourless; it is then dried, powdered and exhausted with æther.

δ. The means of distinguishing fibrine from albumen are unsatisfactory. When fluid, the spontaneous coagulation of the former is decisive, although its non-occurrence does not afford positive proof of its absence. When solid, the best characters are the more bluish colour formed with muriatic acid and the greater action of acetic acid.

The cohesion of fibrine varies greatly; sometimes it forms a firm fibrous clot, at other times an almost diffluent granular mass.

* Berzelius.

ε. *Microscop. char.*—Fibrine exhibits two microscopic forms; one undistinguishable from albumen, the other composed of delicate fibres crossing in various directions. The latter is readily seen in fibrine separated from blood by stirring, or in a drop of blood coagulating under the microscope.

5. Caseine.—This substance varies somewhat in its properties according to the source from which it is derived.

a. Fluid.—It is precipitated by the mineral, acetic and lactic acids*, but the precipitate is soluble on the addition of excess; it is also precipitated by alcohol, chloride of calcium, both acetates of lead, chloride of tin and chromic acid. When boiled, it is not coagulated, but a scum forms upon its surface; this does not occur however without access of oxygen, as for instance in an atmosphere of carbonic acid. It is coagulated by rennet when sugar of milk is present, but not otherwise; the coagulation is really effected by the lactic acid formed from the decomposition of the sugar. Æther coagulates the caseine in cow's milk, but not that in the human fluid. Ferrocyanide of potassium causes a precipitate in the acetic solution of caseine.

Rochleder states that caseine is nearly insoluble in water, that the soluble caseine in milk is combined

* These precipitates are usually stated to be compounds of the caseine with the acid. M. Rochleder however did not find any material difference on analysis between the precipitated substance, after it had been boiled 15 or 20 times with water, and ordinary caseine. It is however highly probable that by this treatment the compound is decomposed and its acid removed.

with potash, soda or lime, and that its coagulation is nothing more than a separation of caseine, resulting from the combination of the acid with the base of the caseine compound. This is however very improbable; otherwise, sufficient of any acid to neutralize the alkali present should precipitate the whole of the caseine, which is not the case.

β. *Solid.*—In this state it is yellowish, swells in water, but does not dissolve in it, nor in alcohol and æther. Acetic acid dissolves it, especially with heat. It is acted upon by mineral acids like albumen. Alkalies dissolve and decompose it when concentrated. When incinerated, it leaves an ash containing carbonate and phosphate of lime; of the latter about 6 per cent. in the caseine which has not been treated with acids.

γ. The caseine of human milk differs principally from that of the cow in its greater solubility in water, the less perfect precipitation by acids, especially dilute sulphuric, muriatic and lactic. Caseine, like albumen, forms two compounds with metallic salts, one soluble and the other insoluble.

Caseine is composed of 10 atoms of proteine + 1 of S. The absence of phosphorus is a remarkable peculiarity; it yielded carbon, 54·96; hydrogen, 7·15; nitrogen, 15·80; oxygen, 21·73; and sulphur, 0·36.

δ. Caseine may be obtained by adding sulphuric acid to skimmed milk, washing the coagulum with water, and decomposing the sulphate with carbonate of lime or lead; the soluble caseine thus obtained however generally contains some of the base used. The lead may be separated by sulphuretted hydro-

gen. Or the precipitate with sulphuric or acetic acid may be boiled repeatedly and in a considerable quantity of water, washed, dried, and the fat removed by æther.

ϵ. *Microscop. char.*—Caseine is composed of minute granules, aggregated as in albumen to form flakes or masses of various sizes, but not possessing any characteristic form or appearance.

6. KERATINE is the name applied by Simon to the peculiar animal substance constituting horn, the epidermis, epithelium, nails, hair, &c. Recent experiments have shown that this substance is, in some cases at least, a compound of proteine and its oxides; but as its properties are tolerably definite, the name may be conveniently retained.

Chem. Prop.—It is colourless when pure, insoluble in water, both hot and cold, also in æther and alcohol. It is soluble in *liquor potassæ*, partially so in ammonia; also soluble in sulphuric acid, imperfectly so in nitric acid, being at the same time coloured yellow. Acetic acid dissolves merely a trace; ferrocyanide of potassium causes little or no precipitate in the solution. By dissolving hair in potash, rendering the solution as slightly acid as possible, a precipitate of proteine falls; on adding more acid, binoxide of proteine is precipitated. It is not known whether the same occurs with all the keratine compounds. When boiled with muriatic acid, the solution becomes reddish-brown.

When incinerated, keratine leaves the same earthy and alkaline salts as albumen or fibrine. In the hair, in addition to these, phosphate of magnesia, silica,

and oxides of iron and manganese have been found. The hair, which has received more attention than any other keratine compound, contains sulphur and a very minute quantity of phosphorus. In preparing hair for analysis, it cannot be digested with alcohol or æther, as these agents act upon the sulphur it contains; consequently the state in which the last substance is contained in it must differ from that of the sulphur in albumen, fibrine or caseine, as in these it is not removed by either æther or alcohol.

Keratine in the hair is composed of $C^{40}H^{33}N^{6}OS^{15}$, giving carbon, 51·529; hydrogen, 6·687; nitrogen, 17·936; sulphur and oxygen, 23·848 per cent. The sulphur averages 5 per cent.

Microscop. char.—The appearances presented by the different varieties of keratine relate principally to the extent of its organization; there is nothing characteristic in the substance itself. The structures formed of it, as far as they come within the limits of this manual, will be described with the fluids in which they occur. For descriptions of the remainder, Mr. Paget's 'Report*' or Henle's 'General Anatomy†' may be consulted.

* 'Report of the Results obtained by the Use of the Microscope in the Study of Human Anatomy,' Brit. and Foreign Med. Review, July 1842.

† 'Allgemeine Anatomie,' von J. Henle, one of the volumes of Sömmering's 'Anatomie.'

II. GELATINOUS COMPOUNDS.

These substances occur extensively in the human body. They swell and become transparent in cold water, dissolve in boiling water; and if the solution be not too dilute, concrete into a jelly on cooling. They are precipitated by chlorine, tannic acid, many earthy and metallic salts, and chloride of platinum, but not by electricity. They are especially distinguished from the proteine compounds by the addition of ferrocyanide of potassium after acetic acid causing no precipitate, by the action of hot water, and their not being precipitated from their solution by acids.

Chevreul found that a certain quantity of tendon, dried at 212°, yielded the same weight of gelatine dried at the same temperature; so that it probably exists already formed in the structures.

7. GELATINE occurs in the bones, skin, serous membranes, cellular tissue, tendons, ligaments and ossified cartilages.

a. Its solution is precipitated by bichloride of mercury, little or not at all by either acetate of lead, copiously by tannic acid, alcohol and chlorine, but not by acids, æther, protosulphate of iron, alum, chloride of calcium, nor alkalies*; protochloride of tin causes a very slight precipitate.

When solid and dried, it is nearly colourless, horny, and does not exhibit any electrical phænomena on trituration. In cold water it swells, forming a plastic mass; in hot water it dissolves, the solution so-

* Alkalies sometimes throw down a slight precipitate of phosphate of lime.

lidifying on cooling. It is insoluble in alcohol and æther. When incinerated it puffs up, and leaves an ash consisting of phosphate of lime.

It is composed of $C^{13} H^{10} N^2 O^5$, yielding carbon, 50·39; hydrogen, 6·64; nitrogen, 18·34; and oxygen, 25·10.

β. To separate gelatine, the substance containing it must be soaked in water, frequently squeezed, and well-washed on a linen bag; the softened moist mass is heated to 120°; it then becomes fluid, and must be filtered; the albuminous and mucous portions are thus separated. In preparing gelatine from bones, the carbonate and phosphate of lime should be previously removed by digestion in dilute muriatic acid.

γ. If gelatine be boiled with excess of caustic potash until ammonia ceases to be developed, leucine and sugar are formed. To separate them, the solution is saturated with sulphuric acid, evaporated to dryness, and alcohol boiled on the residue. The alcoholic solution is then evaporated, and the leucine extracted from the residue by cold alcohol.

δ. *Leucine*, which we have previously noticed in the action of potash upon proteine*, crystallizes in scales resembling cholesterine. It is anhydrous, readily soluble in water and alcohol, but not in æther. It is not precipitated from its solution by any reagent except pernitrate of mercury†. It is composed of $C^{12} H^{12} NO^4$.

ϵ. Gelatine sugar (glycicolle) crystallizes in rhombic prisms, is readily soluble in water, difficultly so in alcohol, and not at all in æther. It gives off no

* It is also formed by fusing potash with caseine.

† Lehmann.

water at 230°. In combination with oxide of lead, it is composed of $C^8 H^7 N^2 O^5$. In the crystallized state it contains 2 atoms of water.

ζ. On ebullition with nitric acid, gelatine yields oxalic, saccharic and artificial tannic acids, as also a fat resembling stearine. Leucine and gelatine sugar are also formed by the action of sulphuric acid on gelatine; and the latter likewise by boiling hippuric acid with muriatic acid for some time.

η. The microscopic appearance of gelatine is not characteristic.

8. Chondrine.—α. This gelatinous substance is principally obtained from the cornea and the permanent cartilages, as those of the nose, the ears and the trachea, as also from the cartilages of the joints and the ribs. It differs in its properties from gelatine. Its solution is precipitated by acetic and the mineral acids, both acetates of lead, alcohol, protosulphate of iron, chromic acid, alum*, chlorine, chloride of tin, tannic acid, protonitrate of mercury* and nitrate of silver*. It is not precipitated by alkalies, æther, chloride of calcium, ferrocyanide of potassium, nor bichloride of mercury. It is but little soluble in cold water. When dried, it is transparent and shining. It does not become electrical when powdered.

It consists of $C^{320} H^{260} N^{40} O^{140} S$, or per cent. carbon, 49·96; hydrogen, 6·63; nitrogen, 14·44; oxygen, 28·59; and sulphur, 0·38. Mulder regards it as a compound of 20 atoms of chondrine free from sulphur ($C^{16} H^{13} N^2 O^7$), combined with 1 atom of

* Those reagents marked with an * redissolve the precipitate in excess.

sulphur. When incinerated, it leaves an ash (about 4 per cent.), consisting principally of phosphate of lime.

β. Chondrine differs principally from gelatine in the action of acids, the acetates of lead, and the solubility of most of its precipitates in excess of the reagents.

γ. It may be obtained from cartilages nearly in the same manner as gelatine from bones, by digesting them, when cut up into small pieces, with water for some time; they are then boiled with water, but for a much longer period than in obtaining gelatine. The chondrine is next precipitated by strong alcohol, the mixture set aside, the alcohol poured off, and the chondrine again dissolved in water.

δ. *Microscop. char.*—The same as those of gelatine.

9. Gelatine of Elastic Tissues.—α. This is obtained from the middle coat of arteries, the yellow ligaments of the vertebral column, &c., by prolonged ebullition.

Its solution is precipitated by muriatic*, nitric*, acetic* and sulphuric* acids, also by tannic acid, chloride of platinum and both acetates of lead, but not by ferrocyanide of potassium. When solid, it swells up, but is little or not at all soluble in cold water; it dissolves in hot water, but is insoluble in æther and alcohol. It has been analysed by Scherer†, who found it composed of carbon, 53·571; hydrogen,

* The reagents marked thus, in excess produce re-solution of the precipitate.

† From the middle coat of the arteries.

7·026; nitrogen, 15·360; and oxygen, 24·042; thus exhibiting the composition of binoxide of proteine ($C^{40} H^{30} N^5 O^{14}$).

β. It differs from gelatine in its concentrated solutions only, gelatinizing, and in being precipitated by acids; fro chondrine, in being precipitated by bichloride of mercury; moreover, the precipitates caused by chloride of platinum, alum and protonitrate of mercury, are soluble in excess of the precipitants, which is not the case with those formed in solutions of gelatine of the elastic tissues. It differs from the solid proteine compounds and keratine by its solubility in boiling water, and from fluid albumen by the reaction of acetic acid.

Mulder remarks that gelatine from elastic tissues has properties which are intermediate between those of chondrine, tritoxide of proteine and gelatine. It seems to be a mixture of them.

γ. Its microscopic appearance is not characteristic.

III. EXTRACTIVE MATTERS.

These occur in every fluid of the body, and were formerly considered as composed of different organic matters, separable by precipitation with various reagents. They had never been submitted to organic analysis, and their separation in the manner described cannot be perfect, since on precipitating organic matters with salts, decomposition of the salt ensues, a portion of the base falling in combination with some of the organic matter, and the acid liberated or the

salt formed retaining either another portion of the organic substance or its combination with the base in solution.

The extractives have been divided into the aqueous, which is soluble in water only; the spirituous, which is soluble in water and dilute alcohol; and the alcoholic, which is soluble in water, dilute and anhydrous alcohol. M. Ludwig has shown that the binoxide of proteine in the extractives of the blood is partly soluble in alcohol, partly not; so that one part would enter into the composition of the aqueous extract, the remainder into that of the spirituous and alcoholic. As the extractives of the blood have alone been accurately examined, I shall omit any notice of those of other fluids and of the substances which have been separated from them, as no light has yet been thrown upon their true nature. The extractive matters of the blood consist of salts and an animal substance, which M. Ludwig has proved to be binoxide of proteine. It is separated from beaten and strained blood by ebullition and stirring until the coagulum assumes a brown colour, then pressed in a linen cloth and the fluid exactly neutralized with very dilute muriatic acid. It is then again quickly heated to ebullition and filtered. The solution, thus freed from albumen, is treated with 4–5 volumes of alcohol of spec. grav. 0·848, which causes the separation of white flakes. These are washed by decantation with alcohol and æther, then dried, exhausted with water, and again dried in the water-bath. Various salts are usually associated with extractive matters; these are the chlorides of ammo-

nium and sodium, sulphates, phosphates and carbonates of soda and potash, alkali in combination with organic acids or other organic matters, and the phosphates of lime and magnesia.

Chevreul obtained a small quantity of a substance which separated from the spirituous extract in a crystalline form, and Wöhler has confirmed its existence: it is called kreatine. It is inodorous, tasteless, neutral, but little soluble in water, readily so in acids. Its aqueous solution is not precipitated by solutions of nitrate of silver, sulphate of copper or iron, diacetate of lead, nor concentrated solution of chloride of platinum. When heated, it evolves ammonia, phosphorous acid and a yellow gas, which partly solidifies into crystals; the odour of hydrocyanic acid is also perceptible. Chevreul considers that it is probably an ammoniacal salt of an acid with a compound radical.

IV. FATTY MATTERS.

These substances may be divided into two classes; —1st, the fatty acids; 2nd, the neutral or saline fats, consisting of acid and base.

The general properties of fatty matters are, that they are lighter than water, render paper transparent, fuse at a lower temperature than that of boiling water, are insoluble in water, soluble in boiling alcohol and æther, being deposited on cooling.

When subjected to destructive distillation, the general products are carbonic, acetic, benzoic, oleic,

margaric, stearic and sebacic acids, acroleine and inflammable gases.

The perfect separation of many of the fats is extremely difficult, nor is their qualitative analysis always an easy task. One of the most important characteristics is their point of fusion or solidification, which is found to be tolerably constant in each. This may be ascertained by taking a capillary tube (easily made over a spirit-lamp); into this a small quantity of the substance is drawn by the mouth; the lower extremity of the tube is then sealed; if the fat is solid at ordinary temperatures, it must be previously fused. The sealed end of the tube is then immersed in water, in which an accurate thermometer is placed, and the temperature of the water must be either raised or lowered (by the addition of hot water or use of freezing mixtures, according as to whether the substance is to be solidified or liquefied) until that point is observed at which the fat becomes either solid or fused. The following table contains the fusing and solidifying points of the fatty matters ordinarily occurring:—

Fatty acids.	Fusing point.	Solidifying point.	Neutral or saline fats.	Fusing point.	Solidifying point.
Stearic..	158°		Stearine....	143°	
Margaric	140°	Below	Margarine..	118°	Below
Oleic ..	....	32°	Oleine	....	24°
			Butyrine ..	....	32°
			Cholesterine	293°	

1. Fatty Acids.

10. Stearic is solid at ordinary temperatures, and occurs but rarely in the human body; it is stated to exist in the free state, and as a soap in the bile.

Chem. prop.—*a.* Inodorous, white and of a pearly aspect; almost insoluble in cold, soluble in boiling alcohol, even when dilute, nearly the whole being deposited on cooling. The alcoholic solution reddens litmus-paper, and is precipitated by metallic salts, the precipitates disappearing when the liquid is heated, again subsiding as it cools.

It is composed of $C^{68} H^{68} O^{5} + HO$, and per cent. of carbon, 76·53; hydrogen, 12·93; and oxygen, 10·52*.

β. Stearic acid is prepared thus:—Saponified tallow is dissolved in 6 or 7 parts of warm water; 40 parts of cold water are then added, and the mixture set aside in a temperate place; bistearate and margarate of potash are deposited. The whole is filtered and washed with cold water; the mixed fluids are collected, concentrated by evaporation, the free potash therein saturated with tartaric acid; water is then added; the bistearates are then again deposited. The salts, after well-washing, are dried and dissolved in boiling alcohol (0·820); on cooling, bistearate with a little margarate of potash is deposited. By repeated solution in alcohol and recrystallization, the bistearate is obtained pure. The salt is decomposed by boiling

* The numbers above adopted are those of Berzelius and Mulder. Redtenbacher and Varrentrapp, however, give $C^{68} H^{66} O^{5} + HO$, and Gottlieb, in a recent paper, $C^{68} H^{67} O^{6} + HO$.

with muriatic acid and water, and the liberated acid is freed from soluble matters by repeated fusion in boiling water.

Microscop. char.—Its crystals exist in the form of rhomboidal tables, the obtuse angles being rounded off. When formed tolerably slowly, the crystals are readily detected; but when hurriedly deposited, they resemble some forms of margarine (*vide* Pl. III. fig. 6).

11. MARGARIC ACID is solid and crystalline, and occurs extensively in human fat combined with glycerine.

Chem. prop.—*a.* But little soluble in cold, readily in hot alcohol, even in hot spirit. The solution reddens litmus, yields precipitates with metallic salts, which disappear by heat and subside on cooling. It is soluble in æther.

Margaric acid is composed of $C^{34}\,H^{34}\,O^{3} + HO$*, yielding carbon, 75·64; hydrogen, 12·86; and oxygen, 11·50 per cent.

β. Margaric acid may be obtained by saponifying human fat or olive oil, decomposing the soap with acetate of lead; the precipitated lead-compound is then treated with boiling æther; the remaining pure margarate of lead is subsequently decomposed by a dilute mineral acid; the margaric acid must then be washed with hot water. It may also be obtained by boiling pure stearic acid with strong nitric acid, or by the destructive distillation of stearic acid.

Microscop. app.—The crystals of margaric acid very much resemble some of those of margarine; they form needles, which are sometimes grouped (Pl. III. fig. 5).

* Redtenbacher and Varrentrapp adopt the numbers $C^{34}H^{33}O^{3} + HO$.

The following table indicates the temperatures at which a mixture of margaric and oleic acid solidifies or fuses:—

Per cent. of margaric acid.	Temperature.	Per cent. of margaric acid.	Temperature.
5	45	50	111
10	63	55	114
15	81	60	116
20	89	65	118
25	97	70	120
30	100	75	121
35	103	80	123
40	106	85	125
45	108	90	127

12. Oleic acid forms a colourless or pale yellow oil.

Chem. prop.—*α.* It powerfully reddens litmus, is soluble in alcohol and æther even when cold; it is not volatile. When subjected to destructive distillation, sebacic acid is produced and condenses in the receiver. The production of this substance, which occurs in the destructive distillation of no fat except oleic acid, or such compounds as contain it, affords a valuable and readily-applicable test of its presence.

Oleic acid is composed of $C^{36} H^{33} O^{3} + HO$*, or carbon, 76·73; hydrogen, 11·89; and oxygen, 11·38 per cent. Its atomic weight is 273.

Its solution is precipitated by metallic salts.

β. Oleic acid may be obtained by decomposing

* Redtenbacher and Varrentrapp adopt the formula $C^{44} H^{39} O^{4} + HO$. Mulder gives $C^{44} H^{40} O^{4} + HO$; the numbers adopted in the text are those of Gottlieb.

oleate of potash or lead with a mineral acid; it is purified by agitation with warm water, and finally separated from any solid fatty acids dissolved in it by gradually cooling it to 32° Fahr., and then filtering.

Microscop. char.—Oleic acid appears in the form of highly refractive globules, undistinguishable by the microscope from oleine, butyrine, or the mixtures of fatty substances which remain fluid at ordinary temperatures.

13. Butyric acid exists in rancid butter, to which it gives its peculiar odour; it also occurs in the contents of the stomach, the secretions of some glands, in the perspiration, and sometimes in the urine. It is a colourless oily fluid of a penetrating, peculiar odour.

Chem. prop.—It is readily soluble in water, alcohol and æther, and is precipitated from its aqueous solution by phosphoric acid. It is volatile, distilling over unchanged at a temperature above 212°. It remains fluid below 15°; its solution is precipitated by diacetate of lead, chloride of tin and alum, but not by acetate of lead, nor nitrate of silver. Butyric acid stains paper like other fluid fats, but the spot disappears by heat. It is composed of C^8 H^7 O^3 * when combined with a base, and in the free state contains 1 atom of water. Its atomic weight is 79. Butyrate of barytes yielded carbon, 31·10; hydrogen, 4·55; oxygen, 15·33; and baryta, 49·02†.

Butyric acid is best prepared by saponifying butter and decomposing the soap by distillation with sul-

* Lerch, Chem. Gaz. vol. ii. p. 377. † Ibid.

phuric acid. The distilled liquid is then saturated with barytic water, and evaporated to dryness.

The saline mass is composed of two portions. The more soluble portion consists of butyrate and caproate of baryta, the more insoluble portion of Chevreul's caprate of baryta. These salts are separated by boiling the saline mass in five or six parts of water; the solution is set aside to crystallize. The crystallized mass is again dissolved in water and evaporated to crystallization. The caproate of baryta is first deposited, so that the entire solution solidifies to a paste consisting of minute needles; these are separated by pressure from the ley, which then on spontaneous evaporation deposits the butyrate of baryta in crystalline laminæ; this may be purified by recrystallization, and subsequently decomposed by phosphoric acid *.

14. Sebacic acid.—This substance never occurs in the human body, but as its production on destructive distillation of any fat is a valuable test of the presence of oleic acid, either free or combined, it is well worthy of a notice. It is solid, and forms pearly scales; is soluble in hot water, alcohol and æther, and reddens litmus.

It is composed of $C^{10} H^8 O^3 + HO$, yielding carbon, 60·01; hydrogen, 8·81; and oxygen, 31·18. Its atomic weight is 92.

* Lerch, *l. c.* This author has shown that butter sometimes yields no butyric or caproic acids, but in their place vaccinic acid, the composition of which is nearly equal to the sum of the constituents of the other two. If butyrate of baryta is present, the first crystals which separate do not effloresce.

Its alkaline salts are readily soluble in water; the earthy and metallic salts are heavy and insoluble.

It is obtained by subjecting oleic acid, or any substance containing it, to destructive distillation, boiling the product with water, filtering through a moistened filter; the acid crystallizes from the solution on cooling or by evaporation.

Microscop. char.—Sebacic acid assumes two principal forms, one prismatic, the other scaly. The former contains within it some curious crystalline bodies resembling nuclei, the latter exhibits large irregular scales, somewhat resembling cholesterine, but not having its peculiar form (*vide* Pl. III. fig. 4).

2. Neutral or Saline Fats.

These are compounds of the fatty acids with a base, which is generally glycerine, when otherwise it will be noticed under the neutral fat in which it occurs. These are the usual forms in which fats occur in the human body.

15. Stearine exists abundantly in hog's lard, suet, &c., but rarely occurs in human fat, where it is replaced by margarine; it is solid, white, forming a shining pearly substance.

Chem. prop.—Is insoluble in water and cold alcohol, slightly so in the latter when hot; but little soluble in cold æther, readily so in hot. When dry, it is readily pulverized. Its solution is not precipitated by metallic salts. Stearine is a compound of stearic acid and glycerine. When boiled with an alkali, the latter combines with the acid, the glycerine being set free.

Stearine is a bistearate of glycerine + 2 atoms of water, or $C^{71}\ H^{72}\ O^{8}$ (Mulder).

To procure stearine, fat must be subjected to heat so as to liberate the fatty matter: the latter is then treated with an equal weight of æther and strongly agitated; this is then poured off and replaced several times by fresh æther. The æther dissolves out the margarine and oleine. The mass is then pressed in bibulous paper, and the stearine may be obtained pure by recrystallization from boiling æther.

Microscop. char.—Stearine does not ordinarily exhibit any defined crystalline form. When deposited on the cooling of its boiling alcoholic solution, it sometimes appears as figured in Pl. III. fig. 2.

16. MARGARINE occurs abundantly in human fat, almost invariably mixed with oleine. It is solid and white.

Chem. prop.—It is very slightly soluble in cold, but more in hot alcohol, readily so in hot æther, being deposited as the solution cools. Its alcoholic solution is not precipitated by spirituous solutions of metallic salts.

It is composed of $C^{37}\ H^{36}\ O^{4}$ (Mul.).

Pure margarine is procured with great difficulty. The fat or oil containing it should be cooled, and the elaine removed either by filtration or pressure between blotting-paper and subsequent washing with cold alcohol. It may be further purified by recrystallization several times from alcohol.

Microscop. char.—It forms stellate groups of crystalline needles, as in Pl. III. fig. 1 (*a*, *c*), or long delicate ramified needles (*b*); the crystals are small, and with a low power appear in little tufts.

17. Oleine, when pure, is fluid and colourless, and is with great difficulty perfectly separated from margarine and stearine.

Chem. prop.—Soluble in cold alcohol and æther; very much so in them when boiling. It is not precipitated by spirituous solutions of metallic salts, nor is it volatile.

It is composed of C^{91} H^{84} O^{11}.

It may be procured by pressing the fats and oils which contain it between bibulous paper, after they have been cooled to between 28° and 32°. The paper is then boiled with alcohol; this dissolves the elaine, which must be freed from the former by heat and washing with water.

Microscop. char.—Undistinguishable from elaic acid.

18. Butyrine occurs in milk, some secretions, and in abnormal cysts. It forms a white or pale yellow fluid.

Chem. prop.—It is insoluble in water, but soluble in cold, and especially hot alcohol, as well as in æther. When saponified with potash, butyric, caproic, capric, perhaps oleic and margaric acids, as also glycerine, are evolved.

It is most probable that some of these substances arise from the decomposition of other fatty matters which are mixed with the butyrine, as the latter is unknown in a state of purity.

It may be procured by melting butter and retaining it for several days at a temperature of 66° Fahr.; a considerable quantity of stearine and margarine is then deposited in a granular form; the fluid oil, consisting of butyrine and elaine, is filtered and agitated

with an equal volume of alcohol (·796) at 66°; this dissolves nearly the whole of the butyrine. The solution, after evaporation, is slightly acid, and must be digested with a little carbonate of magnesia and water. It is then washed, again dissolved in alcohol, and the latter removed by evaporation.

19. CHOLESTERINE frequently occurs in the crystalline state in animal fluids, in solution in the blood, bile, fluid of hydrocele, and I found it in the fluid of uterine hydatids. It also occurs in biliary calculi, the brain, atheromatous tumors, &c.

Chem. prop.—It is solid and crystalline, insoluble in water; soluble in hot but little so in cold alcohol; also soluble in æther. It assumes a blood-red colour from the action of sulphuric acid.

When boiled with nitric acid, cholesteric acid is formed; this is but little soluble in water, readily so in alcohol and æther; fuses at 136°, and crystallizes in yellow needles.

It is not saponified by alkaline solutions, but is so by fusion with hydrate of potash. It resembles oleine, stearine and margarine, in being a saline fat, *i. e.* a compound of an acid and base. The base, however, is not glycerine, but a basic resin, which, as well as the acid with which it is combined, has not been sufficiently examined. Cholesterine is composed of $C^{37}\ H^{32}\ O$.

Cholesterine may be procured from biliary calculi by treating them with boiling water, pulverization, and boiling alcohol on the dry powder; the solution must be filtered whilst hot; the cholesterine is deposited on cooling, and may be purified by treatment with cold alcohol, re-solution and crystallization.

Ebullition with a little potash removes any fatty acids. It may be obtained from the brain by drying it in a water-bath, exhausting the residue with æther, then with boiling alcohol; as the alcohol cools a white powder falls. On distilling the æthereal solution a residue is left, from which boiling alcohol extracts cholesterine. The alcoholic solutions are mixed, three-fourths distilled off, and the remainder allowed to cool; another white pulverulent fat subsides. The precipitates are treated with cold æther; on the evaporation of the æthereal solution, the cholesterine crystallizes and is purified by solution in boiling alcohol.

Microscop. char.—Cholesterine is readily distinguished by its peculiar thin rhomboidal tables or plates*; the angles are sometimes truncated (Pl. III. fig. 8).

20. Glycerine.—This principle never occurs in the free state, except when artificially formed. It exists in margarine, stearine, butyrine and oleine, in combination with the fatty acids. In this state it is anhydrous, but when set free by saponification, it takes up an atom of water. It forms a syrupy, transparent, yellowish fluid; its sp. gr. at 60° being 1·280. It reacts with Trommer's test, as also with Pettenkofer's test, like grape-sugar.

Chem. prop.—*α.* It is readily soluble in water and alcohol, but not in æther. It is unchanged by ammonia, acetic acid, bichloride of mercury, either acetate of lead, chloride of tin, alum or tannic acid;

* These are generally found floating on the surface of the fluid, although cholesterine is heavier than water.

but is slightly precipitated by nitrate of silver. It does not crystallize, nor does it ferment with yeast.

β. When glycerine is subjected to destructive distillation, acroleine is evolved, and may be obtained pure by the distillation of glycerine with anhydrous phosphoric acid; it is formed during the destructive distillation of no substance except glycerine, or those compounds containing it. For this reason, as well as from its most pungent and irritating fumes, it is a valuable test of the presence of glycerine and most fats.

Anhydrous glycerine is composed of $C^6 H^7 O^5 + HO$; in the ordinary state it contains 1 atom of water. Berzelius regards it as the hydrated oxide of a radical (lipyle, $C^3 H^2$), hence $2C^3 H^2 O + 3HO$.

γ. Acroleine is liquid, colourless, soluble in water, more so in æther, boils at 126° Fahr., and is lighter than water; it is soon decomposed. It consists of $C^6 H^4 O^2$.

δ. Glycerine combines with sulphuric acid forming sulpho-glyceric acid. This is a thin, colourless liquid, which is readily decomposed, even by evaporation *in vacuo*. It forms readily-soluble compounds with lime and baryta.

The lime salt is composed of $C^6 H^7 O^5, 2SO^3, CaO$.

It may be procured by mixing one part of sulphuric acid with half a part of glycerine, dilution with water, and the addition of milk of lime until the solution is saturated. The sulpho-glycerate of lime remaining dissolved in the filtered liquid is decomposed by oxalic acid.

Phospho-glyceric acid has just been discovered by M. Pelouze, and has been found by M. Gobley in

the yolk of the egg, and very probably occurs in the human body. It forms a thick, viscid, uncrystallizable liquid, very soluble in water and alcohol. It contains no phosphoric acid as such, and leaves an acid cinder on incineration.

It consists of $C^6 H^7 O^5$, $P^2 O^5$, 2CaO.

ε. Glycerine may be prepared by saponifying fatty matter with oxide of lead, or any alkali, and water; the water lost by evaporation should be constantly replaced. When the fat is saponified, the glycerine is found in the solution; it must be freed from lead by sulphuretted hydrogen, boiled with animal charcoal and then evaporated.

21. Animal soaps.—α. These substances are combinations of the fatty acids with the alkalies. They are but little soluble in cold water; more so in hot; slightly soluble in alcohol, especially when hot; very slightly so in æther even when hot. They are decomposed by heating with acids. When the aqueous solutions of the neutral soaps are copiously diluted with water, acid salts are precipitated in a crystalline form, free alkali remaining in solution.

β. The alkaline soaps are prepared by boiling the neutral fatty matters for some time with a rather dilute solution of caustic alkali, replacing the water lost by evaporation; at a certain period the mass forms a jelly, which by continued heat, if sufficient water and alkali be present, becomes perfectly clear. The soap is separated from free alkali and glycerine by adding chloride of sodium to it whilst hot, until gelatinous flocculi and a perfectly clear liquid are

formed. It may be purified by melting in an alkaline solution of chloride of sodium.

γ. The soaps may also be directly formed by gently heating the fatty acids with caustic or carbonated alkalies.

δ. The qualitative and quantitative analysis of the fats generally is rather a difficult procedure. The evolution of acroleine on the destructive distillation of the residue of the evaporation of the æthereal extract of any fluid, is sufficient evidence of the presence of fats containing glycerine; as has been stated, this is a product of decomposition of glycerine, which exists in oleine and margarine, the two fatty matters most commonly occurring in animal fluids. Butyric acid is separated by distillation. Such matters as are taken up by the æther, and are soluble in water, may be removed by washing the fats with that fluid. The presence of the fatty acids may be proved by treating the alcoholic solution with acetate of lead or copper. The reagents precipitate almost the whole of the fatty acids, leaving the neutral fats, which may be removed by evaporation and the addition of water. The fats must then be saponified; cholesterine is thus left unacted upon. This may be extracted by the action of æther upon the residue of the saponified fat after evaporation. The soaps are then treated with muriatic acid; if the odour of butyric acid is evolved, butyric, capric and caproic acids are present. We can then ascertain with tolerable accuracy the relative admixture of oleic and margaric, or stearic acid by the point of fusion of the remaining fatty matters (p. 22, and 25). The mi-

croscope will also assist in the determination of the nature of the fatty matters. The fluid fats are undistinguishable by its aid from each other, but are so from the solid; cholesterine is readily thus distinguished. The characters of the others have been detailed (see also Pl. III. fig. 1 to 8).

V. ORGANIC ACIDS.

22. Lactic acid.—It is doubtful whether this acid is so generally diffused in the animal fluids as was formerly supposed. Recent experiments have shown that it in all probability does not occur in either the blood or urine. Many of its properties are mentioned in Part I. p. 29. It is but little soluble in æther, and has a more powerful affinity for bases than acetic acid, it therefore decomposes the salts of that acid. We cannot conclude as to its presence, nor determine its quantity from the carbonated alkali found in the ash, as stated in Part I. p. 30, as this may depend upon the decomposition of other substances. Lactic acid reduces the silver in the nitrate to the metallic state when heated with it. The composition of anhydrous lactic acid per cent. is, carbon, 44·92; hydrogen, 6·55; and oxygen, 48·53; when hydrated, C 40·46, H 6·61, O 52·93. Its atomic weight is 81 (*vide* Part I. p. 28). The crystalline sublimate (*l. c.*) is called lactide.

Lactic acid may be obtained by digesting milk in a state of fermentation with milk, sugar, and carbonate of zinc, at a gentle heat; the solution is then

boiled and filtered whilst hot; on evaporation a crystalline lactate of zinc is obtained; this is then decomposed by baryta, which is subsequently precipitated from the barytic compound by the careful addition of sulphuric acid: or it may be obtained by digesting well-washed moist caseine with cane-sugar and powdered chalk for some weeks at a temperature of about 90°, replacing the water lost by evaporation. The crystalline mass thus obtained is filtered through linen, pressed, dissolved in boiling water, and exposed to the cold, the lactate of lime then crystallizes. This salt may be decomposed by hydrochloric acid.

In detecting lactic acid the following process may be adopted*. The diluted fluid is boiled with milk of lime in excess, until all fumes of ammonia or coagulable matters are dissipated; it is then evaporated to dryness in a water-bath. The extract is treated with alcohol (·830), the solution filtered, and the bases separated by sulphuric acid diluted with alcohol. Every trace of acid is then removed by digestion with recently precipitated carbonate of lead. The solution is filtered, the lead removed by sulphuretted hydrogen, again filtered, and after slight evaporation, diluted with water, and gently heated with recently precipitated carbonate of zinc and filtered whilst hot. The solution is evaporated to dryness, the powdered residue treated with alcohol, and the solution filtered. When this filtered solution is evaporated to the consistence of a syrup, the

* M. Enderlin by this process was enabled to detect a very small quantity of lactate of soda which had been added to blood.

lactate of zinc crystallizes; or if strong alcohol be added to it, the lactate is precipitated. The crystals must then be examined as to their peculiar form (Pl. III. fig. 10); they are usually four-sided right prisms with dihedral summits, but sometimes form mere plates, with two-sided extremities, or are combined in aigrettes.

23. Acetic acid.—This acid has been found in various animal fluids, as the bullæ of pemphigus, the saliva of a mercurialized patient, the gastric juice, the perspiration, milk, and in putrid urine.

Chem. prop.—As ordinarily occurring, its properties are well known. It is very volatile. Its salts are soluble in water; those found in animal fluids are also soluble in alcohol; and when they are heated with sulphuric acid, the acetic odour is evolved. Acetic acid scarcely alters a solution of iron, but the solution of a soluble acetate renders it of a blood-red colour. When its alkaline salts are incinerated, a carbonate of the base remains. Acetic acid is not affected by nitrate of silver, neutral acetates however cause a precipitate which is soluble by considerable dilution. It boils at 219°. Acetic acid is distinguished from lactic acid by its volatility, peculiar odour, and action on salts of iron; the peculiar reaction of lime with lactate of copper may assist us in recognizing lactic acid when acetic acid is also present; when lime in excess is added to lactate of copper, the solution retains its colour, a portion only of the oxide of copper being precipitated; with acetate of copper the solution is decolorized, the whole of the oxide being thrown down. From bu-

tyric acid it is distinguished by its odour, not staining paper, and its solution not being precipitated by phosphoric acid.

It is composed of $C^4 H^3 O^3$, yielding carbon, 47·54; hydrogen, 5·82; and oxygen, 46·64. Its atomic weight is 51.

Quantitatively it may be estimated by distillation; the distillate is to be neutralized with baryta, excess of this removed by carbonic acid, the solution is then gently heated, evaporated to dryness, and the weight of the acid estimated from that of the residue; or it may be incinerated and its amount calculated from that of the carbonate left. To separate it from the acetates, evaporate the solution to dryness and then distil it with sulphuric acid, and proceed as above.

24. Hydrocyanic acid.—We have no satisfactory evidence of the occurrence of this poison in human secretions.

Its ordinary properties are well known. It is very volatile.

The alkaline cyanides are soluble in water, and evolve hydrocyanic acid when treated with dilute acids.

The most important means of recognizing this acid are as follow :—

1. Nitrate of silver causes a white precipitate in its solution and that of its soluble salts; this is unaffected by light and insoluble in cold nitric acid, both dilute and concentrated, but dissolved by either on ebullition. It is also soluble in ammonia.

2. When treated with solution of potash in excess, and a mixture of a proto- and persalt of iron added,

a reddish-brown or greenish precipitate is formed; if muriatic acid be next added, prussian blue remains; the muriatic acid dissolves any protoxide or peroxide mixed with the latter, and disguising its characteristic colour.

It may be separated from a fluid by distillation in a water-bath, alcohol having been previously added. If the fluid contain an alkali, or alkali be formed during the distillation, a little sulphuric acid should be previously added. The distillate should then be neutralized with potash; the alcohol driven off by a gentle heat, and the residue tested as above.

25. FORMIC ACID has been supposed to occur in the urine. It is a colourless fluid, boils at 210°, is not precipitated by nitrate of silver and protonitrate of mercury, but its soluble salts are; if the solutions were concentrated, the solutions become black from the reduction of the silver and mercurial salts; this ensues immediately if they are heated. The precipitates are composed of the reduced metals. When a solution of perchloride of iron is added to one of formic acid or a formate, a blood-red colour is produced, as with acetates and sulphocyanic acid, or sulphocyanates. The reaction with nitrate of silver and chloride of iron would serve to distinguish this acid. Since under some circumstances the acetate of mercury is reduced by heat, and the acetates react with chloride of iron in the same manner as the formic acid or formates, the mercurial test should not be relied upon.

Formic acid is composed of $C^2 H O^3, HO$. Its atomic weight is 37.

26. Benzoic acid occurs in putrid urine, and may probably hereafter be shown occasionally to replace hippuric acid in the urine of man, as occurs in some animals.

It is but little soluble in cold water, more so in hot, and readily so in alcohol and æther. It sublimes readily by heat.

It consists of $C^{14}\ H^{5}\ O^{3} + HO$. Its atomic weight is 113.

Its crystalline form has been noticed in Part I. p. 44. See also Pl. IV. fig. 24.

27. Oxalic acid has been found in the urine only (Part I. p. 45).

It is soluble in water and alcohol, and effloresces in the air. When heated with sulphuric acid, it is decomposed, carbonic acid and oxide being evolved, but the mixture is not blackened. Its solution and that of its soluble salts are precipitated by solution of sulphate of lime; the precipitate is insoluble in acetic acid and muriate of ammonia, but soluble in nitric and oxalic acids.

It is composed of $C^{2}\ O^{3} + 3HO$. Its atomic weight is 36.

Its crystals are either four-sided prisms, or rhombic plates.

28. Oxaluric acid has never been found in animal fluids, but its occurrence in the urine is not improbable.

It forms a white crystalline powder, and is difficultly soluble in water. When its solution is boiled, it is resolved into oxalic acid and oxalate of urea.

It is composed of $C^6 H^3 N^2 O^7 + HO$. Its atomic weight is 123.

It may be obtained by treating a solution of uric acid in dilute nitric acid with excess of ammonia. Oxalurate of ammonia crystallizes on evaporation. This is then decomposed by a mineral acid.

29. TARTARIC ACID has been found in diabetic urine in combination with lime.

It is readily soluble in water, but with difficulty in alcohol. Its crystals are acute rhombic prisms.

It is composed of $C^4 H^2 O^5$; its atomic weight is 66.

The bitartrate of potash is figured in Pl. IV. fig. 27, and the tartrate of lime in Pl. IV. fig. 22. The tartrate of lime is readily distinguished from the oxalate by its form.

VI. INORGANIC MATTERS.

1. ACIDIFIABLE SUBSTANCES AND ACIDS.

30. SULPHUR occurs in minute quantity in the proteine compounds, gelatine, bile, &c.

Its properties are too well known to require description. To detect sulphur, the suspected substance or liquid should be boiled with a solution of oxide of lead in solution of potash; if blackening occur, sulphur is present. The most certain method of detecting sulphur is to wash away all soluble substances from the suspected matter, then to dry it and incinerate it with the addition of nitric acid, or what is better, a mixture of nitrate of potash and carbo-

nate of barytes. The residue is exhausted with water and dilute nitric acid, the sulphate of baryta is left.

In insoluble organic compounds, the sulphur may be separated quantitatively by treating them with water and acetic acid; then digesting for some time with nitric acid, the sulphuric acid thus formed is then precipitated by baryta (29) and the amount of sulphur calculated. 100 parts of sulphate of baryta are = 13·797 sulphur.

31. Sulphuric acid is a common constituent of the ash of animal fluids. It may be formed by the oxidation of the sulphur existing in the liquid or solid, and thus be a product and not an educt, as in milk.

It is very readily detected by the precipitate caused in its solution by any soluble barytic salt; this precipitate is insoluble in all acids. The nitrate or the chloride is best used for this purpose, and the solution should be previously acidified with nitric acid (*vide* Part I. p. 25).

32. Muriatic acid has long been supposed to occur in the stomach in the free state, and the question cannot yet be considered as decided. Combined with soda it is found abundantly in all animal fluids.

It is readily recognized and estimated by means of nitrate of silver (*vide* Part I. p. 25). Care must be taken to distinguish the chloride of silver from the cyanide*, with which it has been confounded. This may be avoided by recollecting that the cyanide

* This is undoubtedly sometimes formed by the incineration of animal matters, either containing much alkali, or to which such has been added.

is unaltered by light, whilst the chloride is blackened; they are both insoluble in cold dilute and concentrated nitric acid, but the cyanide is dissolved by the boiling concentrated and dilute acid. Both are soluble in ammonia. In estimating the muriatic acid, the cautions given in Part I. p. 25 should also be attended to. 100 parts of chloride of silver are =25·366 muriatic acid.

When free muriatic acid, muriate of ammonia, and fixed alkaline chlorides occur together, they may be thus estimated: divide the liquid into three parts, evaporate one to dryness and incinerate the extract, the ash dissolved in water and treated with nitrate of silver, &c. yields the amount of fixed chlorides, the muriatic acid and ammonia being volatilized; the second portion is very accurately neutralized with potash, evaporated, incinerated, and treated as above; the increase in the quantity of chlorine arises from the free muriatic acid; the third portion should be supersaturated with potash, evaporated and incinerated, &c. as before, the potassium in the excess of potash retains the chlorine in the acid combined with the ammonia. The second and third curdy precipitates should be boiled with dilute nitric acid to remove any cyanide formed, the chloride of silver not being dissolved by hot nitric acid.

33. Phosphorus exists in most of the proteine compounds.

The amount of phosphorus in an organic substance may be ascertained by previously acting upon it with water and acetic acid. An accurately weighed portion of pure iron is then dissolved by heat in

nitric acid (about 1 part of iron to 2 of acid) with the compound to be analysed; the whole is then precipitated by ammonia*. The precipitate is washed, dried, and heated to redness. By deducting from the weight obtained that of the oxide of iron corresponding to the iron used, we ascertain the weight of the acid. 100 parts of phosphoric acid are = 43·98 parts of phosphorus.

34. Phosphoric acid never occurs free in animal fluids. It is met with in three forms, as a monobasic, bibasic and tribasic acid. The latter occurs most frequently, but the bibasic is sometimes found. The monobasic is also called metaphosphoric, the bibasic pyrophosphoric, and the tribasic is the common acid. The latter is converted into the bibasic by a red heat. The tribasic acid when neutralized by an alkali precipitates solution of silver yellow, the other acids white. By heating the tribasic acid with excess of alkali, it retains the property of yielding a yellow precipitate with silver after a red heat. The monobasic is composed of $P^2 O^5$, HO; the bibasic, $P^2 O^5$, 2HO; the tribasic, $P^2 O^5$, 3HO. The phosphate of silver is soluble in nitric acid and ammonia. Phosphoric acid yields white precipitates with the chlorides of calcium and barium, and which are soluble in muriatic or nitric acids, but precipitated on saturating with ammonia; if however a large quantity of these reagents be used, a portion is retained in solution. It yields, when neutralized, a white precipitate with solution of sulphate of lime, which is soluble in excess of acetic acid, and thus distin-

* If the precipitate be white, too little iron has been used.

guished from the oxalic acid, which gives a precipitate insoluble in acetic acid.

Phosphoric acid, when combined with alkalies, may be estimated,—α, either by the method given in Part I. p. 25; β, by treating the solution with a mixture of sulphate of magnesia, muriate of ammonia and free ammonia, washing with water containing ammonia, drying and incinerating. 100 parts of the pyrophosphate of magnesia left are = 63·36 phosphoric acid; γ, or the iron process alluded to under *phosphorus* (33) may be used.

δ. When combined with earths the following process may be adopted: the compound is dissolved in muriatic or nitric acid and precipitated by sulphuric acid in slight excess, two volumes of alcohol being added at the same time. The solution is filtered, and the precipitate washed with dilute alcohol, dried and weighed. The phosphoric acid may then be calculated from the loss, or, after the evaporation of the alcohol, by the process described above (β).

ε. Or, the compound having been dissolved in muriatic acid (avoiding great excess), solution of perchloride of iron is added and then excess of acetate of soda; if the solution is not red, the chloride is added *guttatim* until it becomes so. The mixture is then boiled for five minutes. If a reddish-brown precipitate does not fall and the solution become colourless, more acetate of soda must be added. The solution is filtered whilst hot, and the precipitate well-washed. It is then dissolved in muriatic acid, tartaric acid and then ammonia added, until the precipitate at first formed is redissolved by excess of the ammonia.

The phosphoric acid is then precipitated by the process described in (34. β). To ensure the removal of every trace of iron, the washed precipitate should finally be dissolved in muriatic acid and precipitated by ammonia*.

35. Carbonic acid is found both free and combined in animal fluids. It may be recognized by being conducted into lime-water; a white precipitate of carbonate of lime is then formed, which is soluble with effervescence in a dilute acid. When existing in any liquid in a free state, it is expelled by a gentle heat. It is readily absorbed by a solution of potash, and is best estimated by absorption with potash, or transmission through a solution of caustic baryta.

36. Hydrofluoric acid occurs in the human bones and teeth in combination with lime, and may be readily detected by heating the pulverized bones with sulphuric acid in a platinum crucible, upon the top of which is placed a glass plate coated with wax, and on which some device has been drawn. The vaporized hydrofluoric acid corrodes the glass, leaving an indelible impression of the device.

It is quantitatively determined by mixing the substance to be analysed with pure silica in a small flask; concentrated sulphuric acid which has been boiled, is then added, and the flask is closed with a cork through which a tube drawn out to a fine point and filled with fused chloride of calcium is passed. Fluoride of silicium is evolved; 1·395 part of this indicates one part of fluorine; 100 parts of fluoride of silicium are = 71·68 of fluorine.

37. Silicic acid or silica is characterized as

* Fresenius.

much by its negative as any other characters. It is insoluble in water, alcohol, and all acids except the hydrofluoric. When fused with potash and treated with water, a portion is dissolved; this is precipitated in a hydrated state on the addition of an acid.

When silica is fused before the blow-pipe with carbonate of soda, effervescence ensues, and a clear transparent glass is formed. In the analysis of animal fluids, the silica remains as an insoluble residue of the action of all the ordinary solvents and acids on the ash. It is unknown whether the remarkable phosphate of magnesia $3MgO, 2P^2O^5$, discovered by Dr. Gregory, occurs in the ash of animal fluids. It is as insoluble as sulphate of baryta, and might therefore be mistaken for silica without proper care.

2. Bases.

38. Potash.—*α*. The presence of potash, which should always be ascertained* in the ash, is recognized by the yellow precipitate caused on the addition of solution of chloride of platinum. Its aqueous solution is also precipitated by tartaric acid in excess, carbazotic and perchloric acids.

β. As potash is usually accompanied by soda in excess, the process for separating potash described here applies principally to its separation from that alkali. The ash is evaporated with slight excess of hydrochloric acid, heated to low redness, dissolved in water, treated with excess of aqueous solution of chloride of platinum, evaporated in the water-bath nearly to dryness, alcohol of ·896 spec. grav. is then added, and after some hours' repose, the undissolved

* Vide Part I. p. 27.

platino-chloride of potassium is separated by filtration, washed with the alcohol and dried at 212° until it ceases to lose weight*; or the following modification may be used: instead of adding aqueous solution of chloride of platinum, $3\frac{3}{4}$ times the weight of the ash of platino-chloride of sodium may be added; the mixture, dissolved in a little water, and evaporated to dryness at a gentle heat, is then treated with spirit (·896), which dissolves chloride of sodium, and any excess of platino-chloride of sodium. The platino-chloride of potassium is then treated as above.

39. Soda.—The best method of detecting soda has been described in Part I. p. 27. Its quantitative analysis is sometimes performed negatively, by deducting the weight of the chloride of potassium from that of the mixed chlorides of sodium and potassium; the difference gives the chloride of sodium.

40. Ammonia does not exist in animal fluids in any considerable quantity, but occurs in small quantity combined with muriatic and perhaps phosphoric acids. It is copiously evolved from animal matters during decomposition. Its salts are volatilized at a heat below that of redness; when heated with potash, the ammonia is evolved; this is recognized as described in Part I. p. 31.

To estimate ammonia quantitatively, the following processes may be used:—

* This should be effected on a filter which has been previously dried at a temperature of 212° until it ceases to lose weight; if the liquid be filtered through this, the precipitate is retained, and the increase in weight of the filter containing the precipitate is equal the weight of the latter.

1st. The substance containing it, either fluid or solid, is distilled with excess of solution of potash by means of a retort and quilled receiver, the quill of the latter dipping into diluted muriatic acid. When rather more than half the solution has passed over and the whole of the ammonia has been evolved, the muriatic solution is treated with excess of chloride of platinum, &c., as directed under potash (38. β). The platino-chloride of ammonium thus obtained contains 7·63 per cent. of ammonia, (NH^3) = 8·08 (NH^4).

2nd. The dried substance is heated, either alone or with hydrate of potash or oxide of lead, in a small tube which is sealed at one extremity. The empty tube thus sealed is first weighed; the salt is then put into it and the whole again weighed; if alkali be used a third weighing must be made after its addition; the open extremity is then drawn out to a fine orifice, which is inserted into a cork which closes one extremity of an equal-sized tube containing hydrate of potash or caustic lime; the other end of the potash tube is furnished with a cork, through the centre of which a small piece of glass tube is passed, or it is drawn out. The whole apparatus is weighed, either joined or separately. Heat is then applied to the tube containing the substance, commencing at the extremity nearest to the potash tube (which should be curved at an obtuse angle); when this portion is heated the lamp should be gradually applied to the remainder of the tube until every trace of ammonia is expelled, which may be known by the application of turmeric or dahlia-paper to the open extremity of

the potash tube. When this is the case, and the apparatus is cold, it is again weighed; the ammonia has escaped, the potash has retained the water; consequently the loss is = the ammonia. Or, another tube, filled with sulphate or chloride of copper, may be attached to the free end of the potash tube; this will absorb the ammonia, the amount of which can then be directly ascertained.

41. Lime, if previously to incineration combined with an organic acid, is found as carbonate in the ash. In the soluble salts it is recognised by solution of oxalate of ammonia causing a precipitate in the neutral solution; and estimated quantitatively, by adding slight excess of ammonia, and then excess of oxalate of ammonia, setting the mixture aside at a gentle heat, filtration and incineration. The ash thus obtained is moistened with solution of carbonate of ammonia, and again heated to low redness; or treated with dilute sulphuric acid, evaporated, and maintained at a red heat until the excess of sulphuric acid is expelled, then weighed as sulphate.

In an insoluble compound, the process described in Part I. p. 27 may be used. It is more easily and accurately accomplished in modifying this process, by adding slight excess of ammonia, then a drop of muriatic or acetic acid, and subsequently excess of oxalate of ammonia, and proceeding as above. Oxalate of lime is insoluble in ammonia, very slightly soluble in oxalic and acetic acid, and readily so in the mineral acids. The microscopic form will assist in its detection (Part I. p. 46).

42. Magnesia, like lime, nearly always occurs as

a phosphate. Solutions of magnesia are precipitated by ammonia unless muriate of ammonia be present, when this is not the case; oxalic acid and oxalates cause no precipitate in a magnesian solution. The problem most frequently occurring is the separation of the phosphate of magnesia from that of lime; this has been solved in Part I. p. 27. The ammonio-phosphate of magnesia is but little soluble in a weak solution of ammonia; this should therefore be used to wash the precipitate.

Another method of separating the lime from the magnesia in the phosphates is by thoroughly fusing them with excess of carbonate of soda, or a mixture of the carbonates of soda and potash. The mass is to be treated with water, and the earthy carbonates dissolved in excess of dilute muriatic acid, slight excess of ammonia is to be added; if any precipitate be formed, more acid must be added, and this again treated with slight excess of ammonia. The lime is precipitated by excess of oxalate of ammonia, warmed and filtered; the filtrate is treated with a mixture of ammonia and phosphate of soda, the precipitate allowed to subside, and well-washed with a weak solution of ammonia.

When magnesia is heated before the blowpipe on charcoal, then moistened with solution of nitrate of cobalt and again heated, it becomes pale red or flesh-coloured.

43. ALUMINA never occurs in the healthy fluids, but has been found in bones and teeth, and in the fæces after the internal use of alum.

Alumina which has been heated to redness is so-

luble in acids with difficulty, but soluble in excess of solution of potash.

The hydrate is insoluble in water, readily soluble in potash, soda and acids, with difficulty in ammonia, and insoluble in carbonate of ammonia. It is precipitated by ammonia or its carbonate from the soluble salts.

When treated before the blowpipe, as directed for magnesia (40), it acquires a bright blue colour.

It may be separated from the phosphates with which it remains mixed in the ash,—1st, by fusion with carbonate of soda or potash, exhausting the mass with water, which dissolves out the alumina, alkali and phosphoric acid, leaving the magnesia and lime; the alumina is then precipitated by supersaturating the filtrate with muriatic acid and the addition of caustic ammonia; 2nd, by digestion with caustic soda, in which it dissolves; 3rd, or by fusion with bisulphate of potash, digestion with water, and precipitation by ammonia. The precipitate should then be dissolved in muriatic acid, and again precipitated by ammonia.

44. Oxide of Iron is a very common ingredient of most secretions, but is generally in small quantity only. It gives the ash a reddish-brown colour. It is detected by digesting the ash in dilute muriatic acid, nearly neutralizing by ammonia, and then adding ferrocyanide of potassium, which causes a blue precipitate if iron be present. Sulphocyanide of potassium and tincture of galls may also be used as tests; with the former the solution must

not be alkaline, and with the latter it should be neutral.

Iron may be separated quantitatively, when not mixed with the phosphates, by precipitation with ammonia; it then falls as peroxide, which must be washed and heated to redness. When mixed with the phosphates, the ash should be fused with carbonate of soda, the mass exhausted with water, the undissolved residue dissolved in excess of muriatic acid, ammonia then added to precipitate the iron, the liquid filtered, the lime separated by oxalate of ammonia, and the magnesia by treating the filtrate with ammonia and phosphate of soda, as in 42.

Or, after fusion with carbonate of soda, and the addition of muriatic acid, and nearly neutralizing with ammonia, the iron may be precipitated by hydrosulphuret of ammonia. When this has ceased to yield a precipitate, the liquid should be gently heated, set aside and filtered; the filter and washed sulphuret are then digested with nitric acid at a gentle heat, filtered to separate any undissolved sulphur, and the peroxide of iron precipitated by ammonia.

Iron may also be detected by the ash becoming magnetic when heated before the blowpipe on charcoal; producing with borax a reddish glass, which becomes yellowish or colourless on cooling in the outer flame, and a bottle- or bluish-green glass in the inner flame.

The remaining metals require but a very short notice, as they occur in extremely minute quantities, if at all, in the healthy body, although they frequently

exist in the fluids after their exhibition medicinally, or as poisons.

45. Oxide of Manganese.—This has been found in the hair and in biliary and vesical calculi.

It is most readily detected by the blowpipe. When heated on platinum-foil with soda, it forms a green glass, which when cold becomes bluish-green. With borax it forms a clear amethystine glass; the colour is destroyed in the reducing flame.

In the moist way, a very delicate test is the action of peroxide of lead and dilute nitric acid at a gentle heat; the liquid becomes of a fine purplish-red colour.

46. Oxides of Copper and Lead are stated to have been detected in, and to exist as natural components of the soft parts and blood of the human body. They have been obtained from the intestines by completely incinerating the well-dried animal matters, dissolving that portion of the ash insoluble in water in muriatic acid, and precipitating the metal by sulphuretted hydrogen; the precipitated sulphuret was dissolved in nitromuriatic acid, sulphuric acid added, and the solution evaporated without filtration. On treating the residue with water, sulphate of copper was removed and sulphate of lead left.

Lead has been detected by deflagrating the matters with nitre, treating the residue with nitric acid, filtering and neutralizing the solution, then testing it with sulphuretted hydrogen, carbonate of potash and iodide of potassium; also copper, by incinerating the substance and treating with nitric acid as above.

The neutralized solutions gave indications of it with sulphuretted hydrogen, ammonia and ferrocyanide of potassium.

Titanic acid has been stated to exist in the blood and renal capsules. I have examined the ash of blood very carefully, both in its ordinary state and after exhaustion with water and muriatic acid. In the former case, the reactions of iron were of course evident, but no purplish tinge could be produced with salt of phosphorus in the inner blowpipe flame on cooling, although this, which is the best test for titanic acid or titanium, readily occurred on adding a little titanic acid.

In the latter case the ash is not entirely deprived of its colour; this arises from the presence of a little silicate of iron, left undissolved by the acid, which also gives the blowpipe reactions of iron, but no trace of titanic acid could be detected.

47. Salts.—The various salts occurring in animal fluids and solids will be mentioned in the analyses of the various compounds in which they occur. A few of their characters, which are important in analysis and facilitate their recognition and separation, will be described here:—

1. *Phosphates of Lime.*—Two of these salts are sometimes met with, a neutral and a basic.

The neutral ($2CaO, P^2O^5$) has only been found in calculi. When heated it fuses with difficulty. It consists of 55·62 acid and 44·38 base.

The basic ($8CaO, 3P^2O^5$).—This salt is very generally diffused through the fluids of the body, and

exists abundantly in the bones. It may be raised to a white heat without fusing.

Berzelius has shown that the phosphate of lime obtained by treating a solution of bone-ash in muriatic acid with ammonia is not always the same. Thus the first precipitate is $8CaO, 3P^2O^5$; but towards the end of the precipitation the true basic phosphate of lime, $3CaO, P^2O^5$, is formed; so that the precipitate may consist of both. The first gives 48·5 per cent. of phosphoric acid, the basic 45·95 per cent. of acid. The compound $8CaO, 3P^2O^5$ is probably therefore $2(3CaO, P^2O^5) + 2CaO, P^2O^5$, *i. e.* a double salt consisting of 1 atom of the neutral with 2 of the basic phosphate. They are both usually amorphous, but the latter is sometimes found in the crystalline form (Part I. Pl. I. fig. 18*; Part II. Pl. IV. fig. 29).

2. *Phosphates of Magnesia.*—These are three. Two have been described in Part I. p. 33; a third occurs in the bones, some calculi, &c. The composition of these phosphates, quoted from Vigla in Part I. p. 33, is incorrect. The prismatic or neutral salt has probably the same composition as regards the phosphoric acid and magnesia as the basic salt, but perhaps contains less ammonia; when dissolved in a dilute acid and precipitated by ammonia, it subsides in the basic form, and is analogous to it in composition. It has never been analysed, therefore its composition is uncertain.

I analysed the bibasic compound, and found that it corresponded with the phosphate artificially pre-

pared by Graham. It was prepared by precipitating the lime from filtered urine by oxalate of ammonia, filtering and adding pure ammonia; it was subsequently dissolved in dilute muriatic acid and re-precipitated by ammonia.

After drying in the air, it lost 54·92 per cent. of water and ammonia at a red heat. The residue yielded,—phosphoric acid, 63·903; magnesia, 36·097 per cent. The ammonia amounted to 6·588. $= NH^4 O, 2MgO, P^2 O^5 + 13HO$.

The third phosphate, found in bones, &c., is composed of $3MgO, P^2 O^5$. It is probably amorphous. It fuses to a clear glass, and gives 54·34 per cent. of phosphoric acid.

The remaining salts worthy of notice are arranged in the following table:—

Notes to the Table.

* The only instance in which carbonate of lime has been found in a crystalline state in any human secretion occurred to myself. I found it in the urine (Med. Gaz., vol. xxxiii. p. 829). It is represented in Plate III. fig. 12.

† 100 parts of chloride of sodium are = 25·36 of muriatic acid.

‡ 100 parts of chloride of silver are = 40·88 of chloride of sodium.

Salt.	Solubility in water.	Solubility in alcohol.	Per-centage of base.	Microscopic form.
Acetate of baryta	Soluble	Soluble	60·01	
Carbonate of lime	Insoluble ...	Insoluble	56·29	Amorphous*.
Carbonate of magnesia.....	Insoluble ...	Insoluble	48·31	Amorphous.
Carbonate of potash.....	Very soluble	Insoluble	68·09	
Carbonate of soda.....	Very soluble	Insoluble	58·58	Acute rhombic prisms.
Chloride of sodium	Very soluble	Sol. when dilute	Part I. p. 26.†	Plate I. fig. 28.
Chloride of ammonium	Very soluble	Soluble	31·83 (NH^3)	Sometimes octahedra, but generally peculiar foliaceous forms (Plate III. fig. 9).
Chloride of potassium	Very soluble	Sol. when dilute	52·45	Cubes, much resembling chloride of sodium, but more frequently combined into peculiar staff-like bodies, the margins of which exhibit portions of the square outlines.
Platino-chloride of potassium	But little sol.	Insoluble	19·334 (KO)	Minute octahedra.
Platino-chloride of sodium ...	Soluble	Soluble.		
Platino-chloride of ammonium	Slightly sol.	Insoluble	8·08 (NH^4)	Same as platino-chloride of potassium.
Chloride of silver.....	.....	.....	Part I. p. 26‡.	
Cyanuret of silver.....	Insoluble ...	Insoluble	80·58 (Ag)	Amorphous.
Oxalate of lime.....	Insoluble ...	Insoluble	38·36	(At 212°). Plate II. fig. 26. Frequently amorphous when precip. hot.
Phosphate of magnesia (pyro-phosphate)	Almost insol.	Insoluble	36·64	
Phosphate of iron (basic) ...	Insoluble ...	Insoluble	42·78	Membranous and fibrous-looking flakes.
Sulphate of lime	Rather insol.	Insoluble	41·18	Excessively minute 6-sided prisms, with dihedral summits.
Sulphate of magnesia	Soluble	Insoluble	34·01	4-sided pr., with dihedral summits.

Having detailed the most important characters of those substances which enter into the composition of animal fluids, it might be expected that it would be an easy task at once to distinguish any one from the others. This will not always be found the case. The inorganic substances are readily recognised; not so, however, the organic. In many instances ultimate analysis will alone decide the question; this, in many cases, may be avoided, and the object attained by the estimation of the atomic weight of the substance, the method of accomplishing which I shall briefly describe. The substance must be purified as completely as possible, if crystalline, by recrystallization. It is then combined with some fixed base. Oxide of lead or silver is generally used for this purpose, because most of their salts are insoluble and anhydrous, and moreover the quantity of the base is susceptible of accurate determination. Supposing then that the substance, as free as possible from other organic matters, has yielded a crystalline or insoluble salt with either of these bases (and for this purpose the substance should be first dissolved in some alkali, and then decomposed by a soluble salt of lead or silver, or precipitated at once by the addition of a soluble salt of lead or silver to its solution). The quantity of water combined with it is first ascertained by heating it to the highest temperature possible without effecting its decomposition. In most cases 212° is sufficient; in a few 390° may be required. The loss is estimated as the water. The amount of base is next sought. If the substance be volatile by heat, and it is combined with lead, the mixture should be treated

with sulphuric acid in excess, then heated, at first gently, finally at a continued red heat, until the whole of the free sulphuric acid is volatilized. When combined with the silver, it is best at once heated to redness. When the substance is not volatile, the compound should be heated to redness without any addition. It sometimes happens that a portion of the lead is reduced to the metallic state, or the silver is converted into carburet. In either of these cases* the residue is treated with nitric acid, and then again heated as before. The amount of oxide of lead is then ascertained, in the first case from that of the sulphate; in the second, the residue is pure oxide. The oxide of silver is calculated from the metallic silver. Having thus ascertained the proportions of the electro-negative body and of the base, the atomic weight of the former is at once found by the following proportion:—The amount of base is to the amount of the electro-negative body as the atomic weight of the base is to that of the electro-negative body. Thus, on distilling putrid urine with sulphuric acid, we observe the deposition of a crystalline sublimate on the neck of the retort; this, when carefully removed, accurately neutralized with ammonia, decomposed with nitrate of silver, washed and dried, yields 47·22 per cent. of metallic silver = 50·71 oxide of silver. Then

$$50{\cdot}71 : 49{\cdot}29 :: 116{\cdot}3 : x.$$

* The oxide of lead may be separated from the metallic lead by acetic acid.

$$\begin{aligned} \log : 4929 &= 3{\cdot}69276 \\ \log : 1163 &= 3{\cdot}06558 \\ &= 6{\cdot}75834 \\ \log : 5071 &= 3{\cdot}70509 \\ &= 3{\cdot}05325 = 113{\cdot}0* \end{aligned}$$

By referring to the atomic weights of the substances, we find at once that this was benzoic acid.

VII. THE BLOOD.

48. The study of the chemistry of the blood, which is certainly more important than that of any other fluid, is at the same time considerably more difficult. We are but imperfectly acquainted with several of its constituents; the processes for its analysis must therefore be imperfect.

The blood is viscid, of higher specific gravity than that of any other animal fluid, and slightly alkaline. The specific gravity has been very differently estimated by various observers; this however most probably depends upon its varying in different individuals; 1050 may be considered as an average. Its

* These logarithms are not used for the purpose of unnecessary parade, but with a view of bringing them prominently before the student, who will find them invaluable in abridging the sums which are constantly arising in analysis. The comparison of the present with the ordinary method renders this at once evident; and it must be remembered that more than half the figures here used are unnecessary, except to render it clear to those unacquainted with the process.

odour, which is most perceptible in that recently drawn, is peculiar, and is said by M. Barruel closely to resemble that of the perspiration, and to be so characteristic that the species and even the sex of the animal from which it has been drawn may be determined by it*; it is stronger in the blood of males than in that of females.

Its colour is different, according to whether it is removed from a vein or an artery. These differences are well known. The colour depends upon a peculiar substance contained within the corpuscles in a fluid state, and called hæmatine; its properties will be described presently.

Whilst circulating in the vessels, it is composed of a liquid, the *Liquor sanguinis*, and corpuscles, which are suspended in the former; the diffusion of the latter in great numbers throughout the mass, gives to the blood its uniform colour.

When allowed to repose after removal from the vessels, it coagulates, forming a coloured clot, or crassamentum, and a fluid portion, which contains a few corpuscles suspended towards the lower part of the vessel, the serum. The clot is not equally red; the upper part is usually of a lighter and brighter colour than the lower, which is very dark, appearing almost black. If, immediately after being drawn, it is stirred with a glass rod, or shaken in a bottle with a loose body of any kind, the coagulum adheres to the body, contains much fewer corpuscles, and is of a much

* The evolution of this odour when dried blood is treated with sulphuric acid has been proposed as a medico-legal test; it is however of little value.

brighter colour than in the former case. Under these circumstances the coagulum consists of fibrine containing but few corpuscles, whilst the fluid part or cruor consists of the serum, containing most of the corpuscles in suspension. The coagulation probably commences immediately the blood has left the vessels; but little alteration can be perceived with the naked eye until from 2 to 3 minutes, when the surface assumes a greenish tinge; the whole mass then becomes gelatinous, progressive separation takes place, and at the end of 20 or 30 minutes the process is completed. It commences sooner, and is sooner completed, in arterial than in venous blood. The caustic alkalies and some salts prevent or delay the coagulation of the blood, especially sulphate of soda, nitrate and acetate of potash, &c. The coagulation is caused by the fibrine alone; the globules have no essential share in the process.

Microscop. char.—The microscopic peculiarities of the blood are its globules. These are of two distinct kinds; the first is composed of very numerous small circular flattened discs, of a yellowish colour, their margins being obtusely rounded, their centres equally depressed on either side; they are about the $\frac{1}{3500}$th of an inch in diameter, and $\frac{1}{4}$th or $\frac{1}{5}$th of this in thickness at the circumference, but much thinner in the depressed centre; this is the average, but they are not uniform, although from their minute size and large number they appear so, unless very highly magnified. They are cells, composed of a highly elastic colourless membrane, which is filled with a coloured fluid. That such is their con-

stitution may be proved by an examination of the phænomena of exosmosis and endosmosis, which they exhibit when mixed with fluids of greater or less density than that which they contain; thus, concentrated saline solutions contract and wrinkle them, whilst they imbibe solutions of low specific gravity, becoming exceedingly distended. When acted upon by water, they become pale or colourless, the colouring matter being dissolved; they finally disappear, some being completely dissolved, others so distended that their walls become too transparent to be perceptible. On the addition of strong saline solutions, solution of iodine, &c., the globules are again partly rendered visible*. When treated with acetic acid, they leave no nuclei. It is stated, that when treated with water and set aside, the corpuscles are dissolved and the nuclei precipitated, forming the whitish deposit which forms under these circumstances. This deposit however principally consists of albumen precipitated from the serous fluid contained within the corpuscles; it also contains some colourless and red corpuscles, which have remained unacted upon. The second kind, called lymph-globules, is composed of spherical corpuscles; these are about one-fourth larger than the former, and fewer in number, being in the proportion of 1 to 5†. They are white, highly refractive, granular on the surface, and specifically lighter than

* The action of water upon the red corpuscles is not uniform; some of them are entirely dissolved, others merely distended, and a few are scarcely at all affected; the latter are generally the smallest. This probably depends upon their different stages of development, and a varying thickness of their walls.

† Wagner. This estimate is certainly too high.

the red corpuscles, and are stated to contain moving molecules in their interior. When acted upon by acetic acid, they are dissolved with the exception of the nuclei, which vary in number, but are generally 2 or 3.

In addition to these bodies, the proper corpuscles of the blood, that fluid also contains, under certain circumstances, globules of oil, the molecular base of the chyle, and another molecular substance exactly similar to the latter in appearance, but differing in chemical properties; and lastly, the minute irregular granules found in all animal fluids.

Those proximate principles which are common to several animal fluids have been already treated of. As we arrive at the consideration of the compound fluids themselves, such substances as are peculiar to them will be described.

49. Fibrine is noticed at page 9. When treated with alcohol or æther, it yields a yellowish-brown acid mass, which is crystalline when cold, and is soluble in cold alcohol; when incinerated, it leaves an alkaline ash, resulting from the decomposition of the acid soap. The quantity yielded by dried fibrine is from 2 to 5 per cent.

50. Globuline is described at p. 8. It is uncertain whether the walls of the corpuscles are composed of this substance, or whether it exists in the fluid portion only; the latter is most probable, the corpuscular walls being constituted of albumen.

51. Hæmatine is the substance to which the colour of the blood is owing:—

a. It exists in two states. We are unable to judge

of the properties of its solution as existing in the blood, because it cannot be separated from the albuminous ingredient with which it is mixed. When dried, it forms a dark, reddish-brown shining mass, insoluble in water, alcohol and æther. It is dissolved by water containing potash ; dilute mineral and acetic acids cause brown precipitates in this solution, which is also precipitated by bichloride of mercury, both acetates of lead, protochloride of tin, nitrate of silver, alum and tannic acid. Ferrocyanide of potassium causes a precipitate in its acid solution. By digestion with dilute sulphuric acid, it is not dissolved, but a part of its iron removed, and its properties become so altered that it is soluble in alcohol and æther*. Hæmatine forms compounds with mineral acids, which are insoluble in water but soluble in alcohol. When triturated with sulphate of soda and alcohol is added, a portion becomes dissolved. When incinerated, it leaves a reddish ash, consisting of oxide of iron (about 10 per cent.), but neither any earthy matter, alkali, sulphur nor phosphorus.

It is composed of $C^{44}\,H^{22}\,N^{3}\,O^{6}\,Fe$, giving per cent.,—carbon, 66·49; hydrogen, 5·30; nitrogen, 10·50; oxygen, 11·01 ; and iron, 6·66.

β. Thus, although it resembles the proteine compounds in so many of its properties, it cannot be referred to them.

When chlorine is passed through hæmatine suspended in water, the colour is destroyed, white flakes are deposited, and the solution contains iron ;

* Lehmann.

the flakes are composed of $C^{44} H^{22} N^3 O^{24} + Cl^6 = Hä + ClO^3$.

The condition of the iron in the hæmatine and its relations to the red colour are still obscure, as is the nature of the hæmatine itself. The iron most probably exists in the metallic state, as it has been shown that by digesting pure hæmatine containing iron with strong sulphuric acid, and subsequent dilution and washing with water, hydrogen is disengaged, and the whole of the iron may be removed, the hæmatine retaining its atomic constitution, colour and general properties. This shows that the iron and colour are quite independent of each other. We shall return to some properties of hæmatine in the consideration of the chemistry of the corpuscles.

γ. Hæmatine may be obtained (α.) by mixing blood, from which the fibrine has been removed by stirring, with a saturated solution of sulphate of soda; the mixture is filtered, and the insoluble corpuscles are boiled with alcohol acidulated with sulphuric acid until the albumen (globuline) remains as a grayish mass. The solutions must be filtered whilst hot, then treated with carbonate of ammonia; this precipitates the albumen (globuline) and the acid; the red filtered fluid is then evaporated to one-twelfth of its volume; the hæmatine subsides as a dark powder, which contains a little fat; after separating this by æther, the hæmatine is pure.

52. Seroline is a fatty matter peculiar to the blood. It forms pearly scales, which fuse at 96°·8 F.

Chem. prop.—It is nearly insoluble in alcohol (0·833) when cold, more so when hot, being again

deposited as the solution cools; it is readily soluble in æther; not saponified by alkalies in solution; is neutral, and evolves ammonia when heated, and is reddened by sulphuric acid like cholesterine. It may be obtained by evaporating the blood to dryness, exhausting the residue with boiling water, again drying, exhausting the residue with boiling alcohol, and filtering whilst hot. On cooling, the seroline is deposited; it must then be washed with cold alcohol.

Microscop. char.—It appears to exist in two forms, one amorphous, the other* composed of filaments, upon which small tubercles or nodes are situated.

53. Fat containing Phosphorus.—If dried and powdered blood be exhausted with water, again dried and powdered, and then exhausted with boiling alcohol, the filtered solution on cooling deposits seroline. The solution filtered from this leaves on evaporation a mixture of several fats; cold alcohol (0·883) removes all but the phosphorized fat. But little is known regarding this fat; it seems to resemble Fremy's cerebric acid. The colour of the red phosphorized fat is due to hæmatine; it is probably merely an admixture of other fats.

54. Corpuscles.—The compound of albumen (globuline) and hæmatosine, forming the contents of the corpuscles, cannot be perfectly separated from the other constituents of the blood. The corpuscles themselves are most perfectly separated by mixing the beaten blood (48) with from 5 to 8 vols. of a saturated solution of sulphate of soda; the mixture is set aside, then poured upon a filter. The greater

* Boudet.

part of the blood-corpuscles remains on the filter, not unaltered, however, for they have lost their primitive form, and become irregular, wrinkled and meniscoidal. It is perhaps better to wash the serum as much as possible from the corpuscles by sulphate of soda and decantation. As soon as the sulphatic solution ceases to dissolve any more albumen, filter, and treat the red magma with water; the contents of the globules then become dissolved in the water, which now again gives all the ordinary reactions of albumen (globuline?). In addition to albumen, they also contain carbonate of soda, oxide of iron and earthy phosphates. When their aqueous solution is allowed to repose, a deposit of albumen occurs, just as is the case with all albuminous solutions when diluted; this deposit is not so copious in the solution of corpuscles which have been treated with the sulphate, as it is partly retained in solution by it. This fact also assists us in forming the conclusion, that this deposit does not consist of nuclei nor membranes of the corpuscles, as the latter are insoluble in sulphate of soda.

The aqueous solution of the corpuscles is coagulated by heat, the coagulum assuming a dark reddish brown, and the liquid a pale yellowish colour. It is also precipitated by alcohol, mineral acids, bichloride of mercury, tannic acid, both acetates of lead and electricity. These reactions are important, especially that with heat, as being the best means of recognising blood in the secretions when the globules cannot be detected with the microscope.

When the aqueous solution of the corpuscles is dried, a reddish-black coagulum forms. This is in-

soluble in water, soluble in potash, also in spirit (0·91) by ebullition, again subsiding as the solution cools. The dried corpuscles contain about 5·5 per cent. of hæmatine. Berzelius obtained 1·3 per cent. of ash from them, consisting of carbonate of soda with traces of phosphate, 0·3*; phosphate of lime, 0·1; caustic lime, 0·2; basic phosphate of iron, 0·1; oxide of iron, 0·5; carbonic acid and loss, 0·1.

One of the products of the decomposition of hæmatine, or this substance altered in its properties by the action of reagents, has been called hæmapheine by Simon. It is probably the same substance as that described by Sanson, but no analysis has yet been made of it, so that we are not acquainted with its relation to hæmatine. It seems under certain circumstances to be very readily formed from the latter. It does not occur in the undecomposed blood, but when, from disease, the plasticity of this fluid is diminished, it is readily formed from the hæmatine. It is always formed when the dried corpuscles are boiled with alcohol acidulated with sulphuric acid. It is distinguished from the hæmatine by its solubility in alcohol and æther even when cold; also in water. It leaves a very minute amount of ash, which contains but a trace of oxide of iron. It is not improbable that this substance is hæmatine without the iron.

55. Serum.—The serum is of a pale yellow colour with a tinge of green. Its specific gravity is about 1·030; it is slightly alkaline, and gives all the ordinary reactions of albuminous fluids. When evapo-

* A portion of this phosphate is probably formed by the union of the phosphoric acid in the phosphorized fat with soda.

rated to dryness and incinerated, it leaves an alkaline ash amounting to about 1 per cent., and containing carbonate, sulphate and phosphate of soda, chloride of sodium, with phosphate of lime and magnesia.

When copiously diluted with water, a precipitate of albumen subsides; this does not however occur if it be diluted with a saline solution; and if the alkalinity of serum be destroyed by an acid, and the mixture allowed to repose, at the end of some hours it becomes gelatinous from the separation of the albumen. The alkalinity of the blood in all probability depends upon the presence of carbonate of soda; some of the alkali is also combined with animal matter*. The Giessen school denies the existence of alkaline carbonates in the blood, and asserts that the alkalinity depends upon the presence of tribasic phosphate of soda. In addition to the objections which I have elsewhere made to this view, it appears impossible for free carbonic acid and the tribasic phosphate to exist in this fluid without the latter being decomposed and carbonate of soda being formed, and the presence of carbonic acid in blood has been proved beyond a doubt.

Ludwig has recently shown that the so-called extractives of the blood consist of binoxide of proteine, part of which is soluble in alcohol, the remainder being insoluble. He separates it by heating fresh, beaten and strained blood in an earthenware vessel over an open fire, constantly stirring it; as soon as the mass has acquired a brownish-red colour throughout, it is pressed between the folds of a linen cloth.

* See Med. Gaz., vol. xxxvi. p. 186.

The red alkaline fluid is then exactly neutralized with very dilute muriatic acid, rapidly heated to ebullition and filtered. It is then treated with 4–5 volumes of alcohol (0·848), the mixture set aside; the flakes which subside by repose may be purified by decantation with alcohol, æther and water. Mulder states that metallic salts precipitate tritoxide of proteine from the serum of blood, after the albumen has been removed.

The microscopic appearance of coagulating blood is as follows:—If a drop from a healthy subject be placed under the microscope and immediately examined, the corpuscles are seen irregularly diffused over the surface of the glass*; and if the latter be held between the light and the unarmed eye, the blood appears as a uniform red spot; at the end of about one minute, the red corpuscles under the microscope are seen to unite by their flat surfaces, forming fibres (which much resemble strings of figs); these interlace, leaving intermediate spaces†; if the glass be held up to the naked eye at this moment, the uniform appearance is exchanged for that of a very minute net-work, or alternation of dark red and light spots. After a time the fibres become broken up, and the corpuscles float loosely in the fluid. Within the meshes of the red corpuscles, the white or lymph-globules are distinctly seen floating separately. The solidified fibrine is also seen in various parts of the field, some in a granular form, some in the form of very delicate fibres; these, in some cases, appear to be partly situated within the colourless corpuscles.

* Pl. IV. fig. 16. † Pl. IV. fig. 15.

We now arrive at the consideration of a most difficult question, viz. the cause why the blood sometimes assumes a bright (arterial) and at others a dark (venous) colour. This has been long supposed to arise from the influence of the oxygen of the air, or the agency of saline matters. The following seem to be the most important facts relating to this point:—1st, when blood is exposed to air, or oxygen gas is passed through it, it assumes a bright arterial colour; 2nd, when agitated with hydrogen or carbonic acid, or these gases are passed through, it is rendered almost black; 3rd, when mixed with saline solutions or syrup, it assumes a bright colour, but not that of arterial blood; 4th, white insoluble powders, as chalk or carbonate of magnesia, also render it bright; 5th, after treatment with a saline solution, carbonic acid blackens and oxygen brightens it; 6th, there is no difference in the form of the corpuscles of arterial and venous blood at all comparable, if any, to that produced by saline solutions in those of venous blood; 7th, neither blood which has been mixed with water, nor that which has not, exhibits any perceptible difference in the form of its corpuscles after treatment with carbonic acid and oxygen*; 8th, hydrogen removes carbonic acid from the blood; 9th, blood which has been darkened by either hydrogen or carbonic acid is reddened by oxygen; 10th, bright blood, on dilution with water, yields a bright solution, dark blood a dark solution.

It thus appears that the alteration in the colour of

* Bruch, Marchand.

the blood may be produced by totally distinct causes. Although saline solutions brighten venous blood, the amount of saline matter not being greater in arterial blood than in the former, the effect cannot depend upon this cause; nor can it be connected with the alteration in the form of the corpuscles, as seen from 6 and 7. No particles which could possibly act in the manner alluded to in 4, are present in arterial blood. It cannot depend upon the mere removal of the carbonic acid, which darkens it, as seen from 8 and 2. Recent experiments tend to show that the gases in blood are not in a state of chemical combination, but merely in solution; the carbonic acid may however be in chemical combination with carbonate of soda in the form of bicarbonate, as the condition of the second atom of carbonic acid in the latter is similar to that of the carbonic acid in the blood. The oxygen appears to be the essential agent in producing the bright arterial colour, but the manner in which it accomplishes this is unknown. It is highly probable that the saline matters have no share in the phænomenon. That the influence of oxygen is much more potent is seen from 4. Blood which contains much carbonic acid has turbid corpuscles.

56. Arterial Blood is of lower specific gravity, consequently contains less solid matter, also less fat, albumen, hæmatine, extractive matter and salts than venous blood; the corpuscles also contain less colouring matter, and are stated to be smaller and more uniform in size than in venous blood; but "differences occur in the composition of both kinds of

blood, which are not constant, but vary according to circumstances*."

57. Portal Blood is darker and browner than ordinary venous blood. It is neither reddened by salts nor exposure to the air. It coagulates quickly but imperfectly, and the cohesion of the coagulum is slight. Its serum is reddish, and does not coagulate so quickly or perfectly as that of other blood. It contains an excess of fluid fatty matter, hæmatine and alkaline carbonates, and but little fibrine.

58. Menstrual Blood, or the menstrual secretion, is a compound of the constituents of the blood with those of ordinary mucus. Its colour is due to the red corpuscles. It also contains mucus and epithelium. In some cases it is very pale, and consists of little more than mucus. The fibrine is small in quantity, and less coherent than usual.

The blood in health contains the following ingredients:—

1. Water.

2. Proteine compounds—fibrine, albumen (globuline), binoxide and tritoxide of proteine.

3. Hæmatine.

4. Fatty matters—3 neutral fats, cholesterine, seroline and phosphorized fat; 3 soaps—margarate, oleate and stearate of soda.

5. Extractive matters—binoxide of proteine (*Ludwig*), tritoxide (*Mulder*).

6. Salts:—*a*. Alkaline—sulphates, phosphates, hydrochlorates and carbonates of potash, soda and

* Simon, Med. Chem.

ammonia. β. Earthy—phosphates, carbonates and sulphates of lime and magnesia.

7. Metallic oxides—silica and oxide of iron.

8. Gases—oxygen, carbonic acid and nitrogen.

9. Substances the quantity of which present is exceedingly minute, if any—bile, urea.

10. Matters only occasionally present—sugar.

59. The Analysis of the Blood.—Some general remarks on the difficulties presented in the analysis of the blood have already been made. The best processes for its accomplishment will now be noticed.

1. The following process, adopted by Andral and Gavarret, is perhaps the best, being easily practised upon tolerably large quantities of blood. The blood, whilst flowing, is caught in two equal-sized vessels, each holding about $5\frac{1}{2}$ oz. of water by weight. In one vessel the first and last quarters of the blood are caught; this is set aside to allow of their coagulation. In the other, the second and third quarters are collected; these are immediately beaten with a glass rod to remove the fibrine, which is then carefully washed and dried. When the coagulation of the blood in the first vessel is complete, the serum is carefully separated from the clot, and both are dried. Thus we ascertain the amount of fibrine, of solids of the serum, and of clot; and by the addition of these, the total amount of solids is ascertained; the loss is water. The weight of the dried fibrine and of the solids of the serum is then deducted from that of the dried clot; the difference gives the weight of the corpuscles. A quantity of solid matter is then calculated for the amount of water lost by the clot on

drying, in the same proportion as the solids are to the water in the serum; the weight of this is also deducted from the clot. The quantity of ash may be easily ascertained by separately removing the dried solids from the vessels in which they are contained as perfectly as possible, weighing the portions used, incinerating them, and then calculating the amount for the whole quantity.

2. *Figuier's Process.*—The blood is stirred immediately after having been caught. It is then filtered, the fibrine well-washed, dried, exhausted of fat by æther, and weighed. Some of the blood, freed from the fibrine, is now mixed with twice its volume of a solution of sulphate of soda, of a specific gravity of 1140, or rather less, and the mixture filtered through a previously weighed filter, which has been previously moistened with the saline solution. But few globules pass through. By dipping the filter several times into boiling water, the globules are coagulated and rendered insoluble, and the sulphate of soda removed; the globules are next dried. The albumen is then precipitated from the filtered serum by boiling, washed, dried at 212°, and weighed. The amount of water in the blood is ascertained by drying a separate portion. To render this process more perfect, the fibrine, after having been thoroughly washed, should be pressed between blotting-paper, then weighed, and subsequently dried; the difference between the total weight of blood at first taken and the moist fibrine is then estimated, and the amount of corpuscles and albumen calculated for this quantity if a portion only be used. The salts are found by

subtracting the weight of the albumen, water, fibrine and corpuscles, which have been directly determined, from that of the blood used.

3. Berzelius recommends the following method:— Two portions of the blood are weighed; one is allowed to coagulate spontaneously, the other is dried in the water-bath and the residue weighed. The loss is the water. When the clot of the first portion is perfectly formed, it is carefully removed, cut up into slices with a sharp knife if large and thick, otherwise this is unnecessary. It is then placed upon an open weighed filter, laid upon several pieces of blotting-paper; another weighed filter is then laid upon it, and more pieces of blotting-paper upon this, the whole being kept *in situ* by a weight. The serum is absorbed from the clot by the paper, which must be frequently changed, the weighed filters being always preserved. After proceeding thus, until on applying pressure the clot yields no more fluid to the paper, the serum is pressed out as strongly as possible, and the clot dried *in vacuo* over sulphuric acid in the adhering weighed piece of blotting-paper; it is then weighed in a covered vessel, to prevent the absorption of moisture from the air. The weight of the fibrine and globules is ascertained by subtracting the weight of the weighed paper from that of the dried clot. The latter is then treated with water at 77°–86° F., which must be frequently changed; and the remaining fibrine, when it ceases to colour water, is dried and weighed. Thus we learn the relative quantities of fibrine and corpuscles, the latter being obtained from the water used for washing. The dried and

weighed blood (second portion) is then successively treated with æther, alcohol and boiling water. The exhausted residue, when well-dried, yields the whole of the albuminous constituents. If the weight of the fibrine and globules be subtracted from it, that of the albumen remains. The æthereal solution contains the fat; the alcoholic and aqueous solutions contain the salts and extractives*. In making these analyses, particular attention is requisite to one point, which is the method of drying; this is frequently too carelessly managed. It is best accomplished in a platinum vessel; and as soon as the residue ceases to lose weight in the water-bath, as much as possible should be removed from the vessel, and carefully pulverized in a mortar; a weighed quantity of this is then again dried, and if it lose any more in weight, the amount for the whole quantity should be calculated.

To analyse coagulated blood, a modification of Berzelius's process may be adopted. Thus, treat the clot in the manner already described; weigh it after having been freed from the serum as much as possible by the paper; after washing this, weigh the fibrine, freed from as much water as possible, in the same way, by subtracting the sum of these two weights from the total weight of the blood, the amount of serum is ascertained; then by ascertaining the proportion of the constituents of the serum in a given weight of it, the total amount may be ascertained by calculation. The fibrine, corpuscles, &c. may then be dried and weighed as before.

* Some other processes will be found in the Medical Gazette, vol. xxxvi. p. 547.

Without detailing Simon's process, it may be well to describe one part of it, which may be occasionally useful in separating the dried blood-corpuscles from other animal matters. It was used by him to separate them from the fibrine and albumen. It depends upon the property possessed by boiling weak spirit (0·925) of dissolving the dried corpuscles, or at least a great part of them. The dried matter is pulverized as finely as possible, the fatty matter removed by æther, and the residue treated with the boiling spirit until this ceases to acquire a red colour, and the residue has assumed a dirty or greenish-gray colour. The spirituous extracts are mixed and set aside; the fluid portion is poured off, evaporated to dryness, the residue powdered and mixed with water into a paste, and then mixed with the flakes which have spontaneously subsided. Strong alcohol is then added, which precipitates the albumen and hæmatine of the corpuscles. If it be required to separate the hæmatine from the albumen (globuline), this may be accomplished by pouring strong alcohol on the flakes, and adding dilute sulphuric acid in drops until their colour is changed. The mixture is then set aside, the red tincture poured off, and pure alcohol added to the flakes as long as it becomes coloured. If the flakes do not lose their red colour and appear gray, more acid must be added and the process repeated; when however this is the case, the flakes are washed, dried at 230°, and weighed. The red tinctures are then collected, supersaturated with ammonia, set aside for some hours, filtered, the sulphate of ammonia washed with alcohol, and finally the alcohol evapo-

rated. The hæmatine remains, containing a trace of fat, and perhaps a little sulphate of ammonia; the latter may be removed by water.

This process does not remove the whole of the corpuscles, so that it is approximative only. A portion of the hæmatine moreover is also decomposed, and Simon's hæmapheine formed. In many cases however it is the only one which can be used.

The incinerations of animal matters and extracts are best performed over a gas-burner, or in a muffle in a fire or furnace, the substances being placed in a porcelain or platinum crucible. The operation is performed with a muffle in less time than with any lamp. It is better to burn off the carbon by continuance of the heat, than by the addition of nitric acid or nitrate of ammonia, &c. The ash, when perfectly incinerated, should appear fused. Should any carbon however remain, it may be separated by treating the ash with water and boiling muriatic acid, when it remains undissolved, and may be separated by filtration.

The analysis of the serum may be made,—1st, by evaporating a weighed portion to dryness; the loss indicates the water. The cautions to ensure perfect drying must be carefully attended to. The powdered residue is treated with a small quantity of anhydrous alcohol, and then with æther, until all the fat is removed. The remaining æther is expelled by a gentle heat. The pulverized residue is then treated with *boiling* water, which dissolves the extractives and alkaline salts α, leaving the albumen and earthy salts β. These may be separated by incineration.

The solution α is evaporated to dryness, and the residue *exhausted* with alcohol, which removes the chlorides of potassium and sodium, with some extractive; the latter is dissipated by incineration. The portion undissolved by alcohol is saturated with acetic acid, evaporated to dryness, and the acetate of soda removed by alcohol; on incineration, it leaves the carbonate; the residue consists of phosphate with a little sulphate of soda. The insoluble portion β is incinerated; the albumen is thus burnt off and the earthy salts left.

2nd. A more accurate process is the following:— The serum is evaporated to dryness at 212°, the residue exhausted with boiling water, the solution evaporated to dryness, the residue incinerated, the amount of carbonated alkali ascertained from the quantity of a dilute acid required for its saturation (117); the solution is acidified with nitric acid, and the chlorine precipitated by nitrate of silver in slight excess, the precipitate collected on a filter, dried, fused, &c. The excess of the silver is precipitated by muriatic acid, the solution filtered and treated with nitrate of baryta, the precipitate collected, &c.; excess of baryta is removed with sulphuric acid; a weighed quantity of pure iron is then dissolved in nitric acid and added to the solution; the mixture is treated with excess of ammonia, which throws down a reddish-brown precipitate of basic phosphate of iron, mixed with oxide of iron*; this is collected, &c. and strongly heated. The remaining solution contains the alkalies, which may be separated ac-

* If this precipitate be white, too little iron has been used.

cording to 38 β. The albuminous residue is incinerated; the earthy phosphates are then left, and may be separated according to 41. The quantity of chlorine is calculated from the chloride of silver, the sulphuric acid from the sulphate of baryta, the phosphoric acid as the difference between the quantity of oxide of iron corresponding to the pure iron used and the mixture of phosphate and oxide. By calculating the quantity of the bases corresponding to the acids, and comparing these quantities with those found by the separate platinum analysis of the residue after the separation of the acids, the amount of the bases may be controlled. The process may be somewhat abbreviated by ascertaining the amount of albumen from a separate portion, and incinerating the second at once to obtain the ash.

The following mean of two analyses by Lecanu and Becquerel and Rodier, will serve to give a general idea of the quantities of the various constituents of the blood, although these are so various that no definite proportions can be fixed:—

Water	78·2867	78·5050		
Fibrine	0·2832	0·2200		
Albumen	6·7252	6·9950		
Fat	0·5155	0·1610	Seroline	0·0020
			Phosphorized fat	0·0476
			Cholesterine	0·0089
			Saponified fat	0·1025
Corpuscles	12·6313	13·4150		
Alcoholic extractive	0·1855	0·09 (Extractives).		
Albumen and soda	0·1637			
Alkaline salts	0·7837	0·62		0·6200
Earthy salts and phosphate of iron	0·1757	0·0897	Phosphates	0·0344
			Iron	0·0553
	100·0000		Total ash	0·7097

Denis, in ten experiments, found the mean amount of saline matter in 100 parts of blood = 1·11.

Nasse obtained 0·7942 per cent. of inorganic constituents from the entire blood; these were composed of—

Alkaline and soluble salts	Phosphates	0·0823	0·6672, and
	Sulphates	0·0202	
	Carbonates	0·0957	
	Chloride of sodium	0·4690	
Insoluble substances	Sulphuric acid	0·0052	0·1270 = 0·7942 per cent.
	Phosphoric acid	0·0201	
	Lime	0·0183	
	Peroxide of iron	0·0834	

Becquerel and Rodier obtained—

Alkaline salts			0·56, and
Insoluble substances	Earthy phosphates	0·033	0·089 = 0·649 total per cent.
	Iron	0·056	

On ultimate analysis healthy blood yielded,—carbon, 51·96; hydrogen, 7·25; nitrogen, 15·07; oxygen, 21·30; deducting the ash, C 54·19, H 7·48, N 15·72, and O 22·31.

The dried corpuscles contain about 5 per cent. of hæmatine; the hæmatine contains about 10 per cent. of oxide of iron. The amount of fat in our typical analysis is too great, the average being 0·2 or 0·3 per cent.* The total amount of saline matters is about 1·0 per cent., that of oxide of iron about 0·06–0·07 per cent.

The following may be regarded as the average composition of serum:—

* I inadvertently stated in the Med. Gaz. that the amount of fat in blood averages 2 per cent. It should be 2 parts in 1000.

Water	90·600	
Albumen	7·900	
Extractives, fat and soda	0·599	
Alkaline chlorides	0·600	0·901
Carbonate, phosphate and sulphate of soda	0·210	
Carbonate and phosphate of lime and magnesia	0·091	
	100·000	

The fatty matter of the blood requires a few remarks; it has not however been sufficiently examined to enable us to speak positively as to its nature. It is separated by exhausting the dried and powdered blood with water, again drying, and boiling alcohol on the residue. The alcoholic solution should be filtered whilst boiling-hot; on cooling, it deposits seroline. After separating this, on evaporating the alcoholic solution, four fatty matters are found in the extract. When the latter is acted upon by cold alcohol (0·833), a crystalline fat remains undissolved; this is the phosphorized fat, and somewhat resembles Fremy's cerebric acid. The alcoholic solution on spontaneous evaporation deposits cholesterine; and after separating this, on further evaporation a mixture of margaric and oleic acids with the potash soaps of these acids is left. Lecanu found in the serum only cholesterine, seroline, margaric and oleic acids, but no phosphorized fat.

The fat extracted from fibrine by æther is crystalline when cold, reddens litmus, and is soluble in cold alcohol, leaving an alkaline ash on incineration; thus it appears, partly at least, to consist of an acid soap*.

In addition to the ordinary constituents of the

* Berzelius.

blood which we have just detailed, others are occasionally present, even in the healthy fluid.

60. SUGAR is one of these. It has been found by Mr. McGregor, and recently by Dr. Buchanan, that blood, even from an apparently healthy individual, ferments with yeast; this has also been found to occur in diabetic blood. It would be more satisfactory were more positive means adopted to test the presence of sugar in this fluid; as by procuring the sugar in the solid form, or the application of Trommer's or Pettenkofer's tests; the production of carbonic acid cannot be received as evidence without the growth of the torula (Pt. I. p. 50), as carbonic acid is evolved from the blood under other conditions.

In applying the fermentation test, the serum should be evaporated to dryness, and the residue treated with boiling water. The solution is then treated with a little yeast, and set aside in a warm place; if sugar be present, the evolution of gas and the formation of the white froth occur.

Trommer's test depends upon the power possessed by sugar, of reducing the suboxide of copper to the protoxide. It is this:—

Add a little solution of sulphate of copper to the suspected liquid, then solution of potash in slight excess, and boil the mixture. The oxide of copper at first precipitated is redissolved by the excess of potash, the liquid becoming deep blue; and if sugar be present, on the application of the heat an orange-red precipitate of suboxide of copper falls; if no sugar be present, the precipitate is almost black. As potash at a boiling temperature frequently causes a dark

colour with organic matters, which may obscure the distinct appearance of the reaction, the following method of applying this principle is preferable (Cappezuoli's test):—Add solution of potash to that of sulphate of copper in a test-tube, wash the blue precipitate with water, add it to the suspected liquid, and then enough potash to render the mixture distinctly alkaline. Set the whole aside in a tall glass vessel, no heat being applied. At the end of a few hours, if sugar be present, the blue precipitate is changed in colour, at first upon its surface, finally throughout the whole mass, assuming a canary-yellow tint; this is succeeded by a red one, the protoxide of copper being reduced. This is a beautiful test; the only objection is that it cannot be applied immediately.

The solution may be prepared for its application, either as described above, or by evaporation to dryness, exhausting the residue with boiling alcohol (not strong), again evaporating to dryness, and treating with water.

61. Bilic Acid and Biliary Colouring Matter.—These two substances appear to occur separately, although mixed in the bile, and we now fortunately possess means of recognising each.

It is doubtful whether bilic acid occurs in the blood, but there is no doubt regarding the occurrence of the colouring matter. In the healthy fluid neither can be detected.

The colouring matter is recognised by the peculiar greenish-yellow colour which it imparts to the fluid, as also by the reaction of nitric acid, which causes

it to pass through a series of tints, in which green and red predominate. If the fluid be albuminous, the albumen, when precipitated by nitric acid, assumes a green colour. Bilic acid is recognised by its reactions with sulphuric acid and cane-sugar (Pettenkofer's test). The liquid, or an aqueous solution of the solid suspected to contain it, is treated *guttatim* with two-thirds of its volume of sulphuric acid in a test-tube. From 2 to 5 drops of syrup (1 part sugar to 4–5 water) are then added, and the mixture shaken. The addition of the acid at first precipitates the bilic acid, which is subsequently redissolved, and speedily a beautiful deep reddish-violet colour is produced. In using this excellent test, the temperature of the mixture must be kept below 144° F.; too much sugar must not be added; the sulphuric acid must be free from sulphurous acid, and albumen must be previously removed by ebullition. In some cases, especially where the amount of bilic acid is small, an excess of the acid may be requisite.

To remove the bilic acid and colouring matter, the fluid should be evaporated to dryness, exhausted with strong alcohol, again evaporated to dryness, and the residue dissolved in a small quantity of water.

This test acts equally well with grape-sugar. If properly applied it does not appear liable to fallacy. Albuminous solutions, when very concentrated, produced a similar reaction. If too much syrup be added, the mixture becomes brown from the formation of humus. A certain amount of heat is necessary, or at least facilitates the reaction.

62. Urea.—In all probability urea exists in the

blood in minute quantity, although it cannot be satisfactorily detected. The fact of the extractives of blood causing chloride of sodium to crystallize in octahedra, and to form the peculiar dagger-like crystals (Part I. figs. 30 and 31), cannot be considered as sufficient to decide this point. Some of the crystalline arborizations of muriate of ammonia so nearly resemble those of chloride of sodium crystallized from a solution of urea, that they can hardly be distinguished. In certain diseased conditions there is no doubt of its occurrence. To detect urea in the blood, or in any fluid, evaporate it to dryness in a steam or water-bath, exhaust the residue with strong alcohol, again evaporate, dissolve the residue in a small quantity of water, immerse the mixture in ice-cold water, or in a freezing mixture, and add slight excess of nitric acid. The compound which separates (and one nearly always does so, whether urea is present or not) must then be examined with the microscope. Two substances are generally to be found, viz. globules of oleic acid, or rather a mixture of oleic and margaric acids, and oblique rhomboids of nitrate of soda; if urea be present, it may be distinguished by its characteristic form (Pl. II. fig. 38). It is seldom however that it can be recognised at this stage of the process; if not, the liquid should be digested with excess of carbonate of baryta, then gently evaporated to dryness, exhausted with strong alcohol, again evaporated and treated with the acid in the cold as before; if urea be present, its form may then be recognised; the appearances generally presented are figured in Pl. IV. fig. 20. The crystals of the

nitrate of soda, as found under these circumstances, are figured in Pl. IV. fig. 21. It is well not to use oxalic acid to separate the urea in this process, as it crystallizes itself in the cold, and may give rise to confusion; moreover, the extracts should be thoroughly exhausted with alcohol, as the amount of urea is generally not large, and the evaporations should be performed very carefully and slowly.

63. Milky Blood.—The occasional occurrence of either an entire milkiness of the serum, or the formation of a creamy scum on its surface by repose, has been noticed in several diseases. It has been lately shown to be almost a constant occurrence in the blood withdrawn a few hours after a meal. The milkiness is caused by an immense number of exceedingly minute granules, resembling in appearance those which form the molecular base of the chyle. They are of two totally distinct kinds, one being soluble in æther, the other unaffected by it. When the milkiness is caused by the former, on agitating the serum with æther it entirely disappears, the serum becoming clear; in the latter case the æther floats on the surface, acquiring a yellowish colour from the solution of fatty matter, the lower portion retaining its peculiar aspect. The former substance is probably analogous to the molecular base of the chyle (*vide* Chyle, p. 98). Dr. R. D. Thomson found the latter quite insoluble in both æther and alcohol, but soluble in caustic potash. It contained sulphur. He concluded that it most probably consisted of a proteine compound. Dr. Buchanan found that it might be removed by adding salt to the solution, filtering and

washing. In one case the blood has been found milky and acid from the presence of acid fatty salts. I had an opportunity lately of examining some milky blood which had been withdrawn from a gouty patient. It was uniformly white, from the presence of an immense number of minute granules or molecules. These were separated by solution of chloride of sodium. When dried and treated with æther, they yielded some fatty matter. On ebullition with muriatic acid, the characteristic reddish colour of proteine was produced, and a large number of oily globules, which solidified on cooling, floated on the liquid. These were composed of a fatty acid. The substance was in but small quantity, and I have not yet completed its examination. It decidedly contained no sulphur.

64. Pus is an occasional abnormal ingredient of blood. Donné has proposed the action of ammonia as a test of its presence. If healthy blood be mixed with ammonia, the colour becomes somewhat brighter, and the mixture is rendered clear; when containing pus, it becomes gelatinous, the firmness and quantity of the jelly being proportional to the quantity of pus present. This may be a useful test in some cases, but should not alone be relied upon. The microscope may be much more safely trusted. In using this instrument, care must be taken not to mistake the proper chyle-corpuscles (Chyle, p. 98), or the colourless corpuscles of the blood, for those of pus; the red corpuscles also occasionally present a granular appearance, not very unlike that of globules of pus. The latter may be distinguished from the

former by their spherical form, larger size, whitish colour, and yielding nuclei with acetic acid; whilst the former are yellowish, flattened, and dissolved by acetic acid, leaving no nuclei. The colourless corpuscles of the blood much resemble those of pus, but are smaller and more finely granulated on the surface. The proper chyle-corpuscles are also smaller than those of pus, and occur but rarely.

Pus, when mixed with blood, appears in the serum either in the form of the mucous urinary deposit or in flakes* (160).

65. Buffy Coat.—The appearance of this remarkable formation is well-known. Its ordinary physical properties do not differ from those of fibrine. When freed from the serum by kneading in cold water, and then boiled with water, it yielded 14·2 per cent. of tritoxide of proteine and 85·8 per cent. of binoxide. On organic analysis it yielded—

C 52·53–52·95, H 6·9–7·04, N 15·51, O 25·06–24·5.

Hence it is composed of a mixture of the bin- and tritoxides of proteine. The cause of its formation cannot be explained. It has been observed that if blood be drawn into two separate cups, one of which contains oil, the latter exhibits the buffy coat, whilst the former does not. It is unknown whether the buffy coat is ever composed of fibrine; when produced under the conditions just described, its composition is also unknown.

We have already shown that the oxygen of the air has an undoubted influence upon the corpuscles espe-

* Gendrin.

cially. Now supposing from any cause (and several have been proposed) that the corpuscles in blood which is about to form the buffy coat subside more rapidly, or that the cohesion of the red particles occurring sooner in buffy than in healthy blood squeezes out the *Liquor sanguinis*, which is thus exposed to the air during the coagulation, we can imagine how it *might* occur that in healthy blood during coagulation the fibrine is defended by the corpuscles from the action of the oxygen; whilst in the buffy blood this is not the case, and the fibrine is exposed to the free action of the air, and might form the oxides of proteine. This view would be confirmed *should* the buffy coat formed under oil be found composed of fibrine. These arguments are merely proposed to draw particular attention to the point, and hence to cause the institution of more experiments. I have not noticed Mulder's views on this subject, inasmuch as they do not appear to me at all satisfactory, and he seems to speculate on this matter much more than his experiments entitle him to do.

The microscopic appearances of blood which is about to form a buffy coat are well-marked. The formation of the net-work perceptible to the naked eye, which in healthy blood does not occur until the lapse of about a minute, may be perceived in buffy blood immediately after its removal from the vessel. Moreover, the fibres formed by the apposition of the sides of the red corpuscles under the microscope are immediately visible; hence buffy blood differs essentially from the healthy fluid, and the formation of the buffy coat may thus be foretold.

Buffy blood contains a larger number of colourless corpuscles than the healthy fluid; but the relation these have to the oxides of proteine is not known. In consequence of the formation of the net-work or sponge which we have just mentioned, before the solidification of the fibrine, its contraction is uninterrupted by the latter, and the *Liquor sanguinis* with the colourless corpuscles are squeezed out of the sponge and rise to the surface; so that if we examine a drop from the surface of the blood immediately after it has been drawn into a cup, we find a few colourless corpuscles, as well as the net-work of coloured corpuscles; a little later, the latter having sunk, are nearly absent, a few only being detectable, the colourless corpuscles being much more abundant; at a still later period, these having sunk, almost disappear, the solidified fibrine alone being present.

66. Concretions are occasionally found in the cavities of the heart, which have formed during life. They are composed of fibrine, containing the red corpuscles diffused through them, and, as in the ordinary clot, these are most abundant in the most dependent portion. In the interior of these masses pus is stated to have been found; but, from the observations of Mr. Gulliver, the semifluid matter appears to consist merely of disintegrated pultaceous fibrine; it contains few, if any, corpuscles resembling true pus. Nothing is known of its chemical nature. When examined microscopically, it exhibits an immense number of very minute granules with a few lymph (?) corpuscles. It is more prone to putrefaction than pus.

67. Chyle.—This fluid is so difficult to procure that our knowledge of it is not very satisfactory. It can hardly become an object of pathological examination. It is a neutral milky fluid, of about 1021–4 spec. grav., and varying in its properties according to the part of the lacteal system from which it is withdrawn. Soon after its removal from the vessels it coagulates like blood; the coagulum is reddish when viewed in a mass; this redness is said to be increased by exposure to the air; when examined in small quantity it is not perceptible. Its appearance also varies according to the contents of the alimentary canal at the time of the death of the subject from which it is obtained. If a full meal had been taken a few hours prior to death, and especially if this contained fat, the chyle is perfectly milky; but if digestion was not going on, it resembles lymph in its composition. The milkiness depends upon the presence of a peculiar molecular base. It is entirely removed by æther. The reddish colour depends upon the presence of blood-corpuscles. When allowed to repose, the molecular base partly forms a creamy scum on the surface, but the whole fluid does not become clear.

The minute granules, constituting the molecular base, are not changed by the action of salts, caustic alkalies, nor acetic and muriatic acids. They are instantly dissolved by æther, the chyle becoming transparent, except a small quantity of a light brown or whitish matter, which forms a nearly pellucid *substratum*, sinking towards the bottom of the test-tube, but never entirely reaching it*.

* Gulliver.

The fatty matter of the chyle leaves an alkaline ash, and contains no phosphorus.

Chyle (obtained from the thoracic duct) yielded on analysis—

Water	90·48
Albumen, with traces of fibrine	7·08
Extractives { Aqueous	2·56
Extractives { Alcoholic	0·52
Alkaline chloride, carbonate and sulphate, with traces of phosphate and oxide of iron	0·44
Fatty matters	0·92
	100·00*

The differential characters of chyle and blood are as follow:—The partial or complete absence of the red colour; the low specific gravity; the less distinctly alkaline reaction; the later and more imperfect coagulation; the less number of its corpuscles; their different appearance; the greater amount of fatty matter, but less amount of solids; the imperfect formation of its albumen, which more nearly resembles caseine than the albumen of the blood, and of its fibrine, which more nearly approaches albumen; the free, not saponified state of its fat; its great richness in extractives, diminished quantity of soluble salts; its iron being contained in the serum, instead of the corpuscles; and its greater richness in carbon and poorness in nitrogen than arterial blood†. Sugar has been found in the chyle, and it would be extremely interesting to know whether urea is ever present or not.

Microscop. char.—Before the chyle has passed through the mesenteric glands, it is of a milk-white colour; this is owing to the presence of, *a*, an im-

* Dr. Rees. † Nasse.

mense number of minute granules, of the $\frac{1}{24000}$–$\frac{1}{36000}$th of an inch in diameter (the molecular base); it also contains, β, some free oil-globules; after having passed through the mesenteric glands, it contains, γ, the proper (?) chyle-corpuscles*; these are roundish granulated bodies, some larger and some smaller than the blood-corpuscles, and closely resembling the lymph-globules; δ, a few coloured corpuscles of the blood are occasionally present. When treated with æther, the α and β particles are dissolved, the proper chyle-corpuscles being unaffected. The latter are scarcely affected by acetic acid, nor do they generally yield any distinct nuclei with it, although two or three are sometimes seen†. Chyle may be analysed much in the same manner as the blood; more difficulty is however experienced in separating the fibrine, the texture of which is extremely loose and diffluent.

68. Lymph.—We have even less accurate knowledge of this fluid than of the chyle. It is of a pale yellowish colour, and coagulates in about 10 minutes. The coagulum is gelatinous. It is alkaline, and contains about 3–5 per cent. of solids. It contains much more water than the chyle.

Gmelin found human lymph composed of—

Water	96·10
Fibrine	0·250(?)
Albumen	2·750
Chloride of sodium, free alkali, phosphate of soda, and a substance resembling ptyaline	0·210
Extractives and soda	0·690

* These are surely nothing more than lymph-corpuscles.

† Gulliver.

Marchand found 1·544 per cent. of inorganic constituents.

In microscopic appearance lymph resembles blood which is deprived of the red corpuscles, but it appears to contain a larger number of the colourless globules.

Lymph may be analysed in the same manner as the chyle or serum of the blood.

69. Saliva.—The saliva, as voided from the mouth, is a mixed fluid, consisting of the secretion of the salivary glands with the mucus of the mouth. When allowed to repose, it separates into two layers; the upper is clear, colourless, and somewhat mucous; the lower consists of the same liquid, containing an opake matter in suspension. If the saliva be agitated with water, the mucus is diffused through the liquid, and by repose completely subsides. It has a specific gravity of 1005–8, and appears to be alkaline when food is taken, at other times acid. When diluted with water, it is precipitated by nitrate of silver, both acetates of lead, bichloride of mercury and tannic acid; perchloride of iron causes the liquid to assume a deep red colour, from the formation of sulphocyanide of iron. A milkiness is caused in saliva when mixed with water and filtered by acetic, nitric and muriatic acids; ferrocyanide of potassium causes a precipitate in the muriatic solution. Alum also causes a precipitate, but neither this nor the acetic precipitate is soluble in excess of the precipitant. When boiled a very slight opalescence is caused in its aqueous solution.

Berzelius obtained 0·717 per cent. of solid residue from saliva by evaporation. Spirit removes alkaline chlorides, albuminate of soda and extractive from it.

The portion insoluble in alcohol is slightly alkaline; when neutralized with acetic acid, evaporated and treated with alcohol, acetate of soda is removed. The undissolved residue consists of mucus and ptyaline.

70. PTYALINE somewhat resembles tritoxide of proteine in its characters, but differs from it in some essential points. It is insoluble in alcohol and æther, being precipitated from its aqueous solution by the former, but not by mineral acids, acetic or tannic acids, neither acetate of lead nor bichloride of mercury. It is neutral, and leaves an alkaline ash on incineration.

Ptyaline may be procured by treating the mixture of that substance with mucus, spoken of above, with cold water; the ptyaline is dissolved, the mucus remains. Or, fresh saliva should be neutralized with acetic acid, and then evaporated in a water-bath; the residue is first treated with alcohol and then with spirit; the residue is dissolved in water, and treated with chloride of calcium and ammonia, to precipitate the sulphuric and phosphoric acids; the solution is then neutralized with muriatic acid, evaporated to dryness, and the chlorides extracted with alcohol*. Ptyaline is stated to have been found in vomited fluids, dropsical effusions, &c.

Berzelius found saliva constituted of—

Water	99·29
Ptyaline	0·29
Mucus	0·14
Extractive and alkali	0·09
Chloride of sodium	0·17
Free soda	0·02
	100·00

* Lehmann.

Chloride of calcium, alkaline carbonate, phosphate and sulphate, muriate of ammonia, with phosphate and carbonate of lime and a phosphorized fat, have also been detected in it. Simon found 0·052 per cent. of fat. Tiedemann and Gmelin found 0·25 per cent. of ash, consisting of 0·203 alkaline and 0·047 earthy salts. Saliva contains an exceedingly small quantity of a substance precipitable by acetic, nitric and muriatic acid, as also by ebullition. This appears to consist of albumen with mucus.

The presence of sulphocyanogen in the saliva was clearly shown by Tiedemann and Gmelin thus:— Dried saliva was exhausted with alcohol, the latter removed by distillation, the residue mixed with concentrated phosphoric acid, and the mixture distilled to dryness in a water-bath; the distilled fluid was reddened by a neutral salt of iron. When a portion of the distillate was treated with a mixture of protosulphate of iron and sulphate of copper, a white precipitate was produced, which possessed the property of reddening an acid solution of perchloride of iron. Finally, a mixture of solution of chloride of barium, chromate of potash and muriatic acid (which is clear, and contains chlorine abundantly), when added to and digested with the distillate, became turbid, and gradually deposited sulphate of baryta, formed at the expense of the sulphocyanic acid in the distillate*. The white precipitate spoken of above is 2CuCy2S; the sulphocyanide of copper, CuCy2S, is soluble in water, but is reduced by the protosalt of iron to the

* Berzelius.

sulphocyanuret 2CuCy2S. Acetic acid is volatile, but does not cause a deep red colouring in solutions of iron except when previously neutralized by an alkali; moreover, it does not cause the white precipitate with the solutions of iron and copper. The red colour of the sulphocyanuret of iron is destroyed by bichloride of mercury; that of the acetate is not so. The meconate and formiate of iron are also of a similar colour to that of the sulphocyanuret; they are however readily distinguished by the bichloride of mercury, which does not destroy their colour. That produced by the addition of chloride of iron to the human saliva is destroyed on the addition of the bichloride.

Microscop. app.—This differs but little from that of mucus. Four kinds of corpuscles are recognisable: —α, the minute granules found in all animal fluids; β, mucous globules; these are larger than those in pus, generally yielding a single large nucleus with acetic acid, sometimes not, and being much more slowly acted upon than those of pus; γ, epithelial scales; and δ, occasionally a globule or two of oil. In all probability, the whole of these are, save the last, derived from the mucous membrane. The β globules exhibit moving molecules in their interior.

The pathological alterations of the saliva relate to its acidity or alkalinity, the alteration in properties of its normal constituents, and the addition of foreign ones.

The detection of its acidity needs no notice, except that the paper should be of the most sensitive kind, dahlia-paper prepared without the addition of

either acid or alkali; the amount of acid may be estimated according to 117. The proportion of its constituents may be determined by a process similar to that used in the analysis of the serum of the blood. The principal foreign matters, and those which should be sought for, are fat, 21 δ; the fatty matter should be washed with water; sugar, 60; acetic acid, 23; albumen, 2 δ; urea, 62; bile, 61.

71. Calculi occasionally form in the salivary ducts. They usually consist of ptyaline, mucus, carbonate and phosphate of lime, alkaline salts, sometimes oxides of iron and manganese. They may be analysed by removing the ptyaline and alkaline salts by water; the remainder is best analysed as in 34 ε. Any animal mixed with these substances may be decomposed by incineration.

72. Tartar of the teeth being a deposition principally from the saliva, may be briefly noticed here. It frequently contains ptyaline; this may be extracted by water; muriatic acid dissolves the remainder, except the salivary mucus. Ammonia throws down phosphate of lime, ammonio-magnesian phosphate and some animal matter from the solution. Berzelius found per cent.,—ptyaline, 1·0; salivary mucus, 12·5; earthy phosphates, 79·0; animal matter dissolved by the muriatic acid, 7·5.

When examined with the microscope, it appears composed of an amorphous substance, minute infusoria, and mucus resembling that of the saliva.

73. Gastric Juice.—Notwithstanding the attention which has been bestowed upon this important fluid and the digestive process, the real nature of the

former and the actual part it plays in the latter are still not satisfactorily determined.

The gastric juice is slightly viscid, frothy and colourless, and contains mucus, which impairs its transparency; by filtration however it becomes clear. When digestion is not going on it is neutral, at other times acid. It is composed of free muriatic acid (?), chlorides of sodium, potassium, ammonium, calcium and iron; extractives; an animal matter, soluble in dilute acids and precipitable by persalts of copper and iron; mucus, pepsine and phosphate of lime. It contains neither albumen nor phosphate of soda. Berzelius obtained 1·269 per cent. of solids from it. Beaumont found that it effervesced with carbonated alkalies. We have already described the process from which Dr. Prout arrived at the conclusion that the gastric juice does contain free muriatic acid; there can be no doubt that it does not contain free lactic acid; but it is so difficult to obtain in a pure state, that its properties are likely to remain very obscure.

Various experiments have lately been made, tending to overthrow Dr. Prout's conclusion; but these have unfortunately been instituted upon the gastric fluid mixed with various organic matters which were undergoing digestion, so that on subjecting them to distillation little or no muriatic acid passes over (as pointed out years ago by Tiedemann and Gmelin in their beautiful experiments), it being probably retained, as they suggested, by the organic matters present. The following experiment of MM. Tiedemann and Gmelin appear very decisive upon this

point:—They placed pieces of well-washed limestone in the stomachs of fasting animals, and found subsequently that the gastric juice was no longer acid, but contained a deliquescent salt, which was not decomposed by a red heat, and was proved to be chloride of calcium. Dr. R. D. Thomson distilled the contents of the stomach of a pig after dilution with water and filtration, and found that, although the distillate was acid, it gave no trace of hydrochloric acid with nitrate of silver. 3 portions of the fluid remaining in the retort were next measured out. The first was precipitated by nitrate of silver; nitric acid was then mixed with the liquid and the whole boiled; the precipitate filtered and washed. The second portion was dried and ignited, the residue dissolved in water and precipitated with the nitrate, the solution being acidulated with nitric acid and boiled. The third was exactly neutralized with caustic potash, evaporated and ignited, the residue dissolved in water and precipitated by the nitrate. The results were,—

	Chloride of silver.	Chlorine.	Hydrochloric acid.
1st.	7·81	1·95	2·00
2nd.	7·17	1·79	1·84
3rd.	7·97	1·99	2·04

Now these experiments appear to me susceptible of a different interpretation to that given by the author; for supposing that no hydrochlorate of ammonia was present, (it has been found absent by Dr. Prout, and in this case was not proved to be present) the chlorine might have existed in the form of muriatic acid and chloride of fixed bases; the first precipitate would therefore have contained the chlorine combined with

the fixed bases + that existing as muriatic acid; the second would contain the chlorine of the former alone; the third the same as the first. So that these results are not opposed to Dr. Prout's view*.

74. Pepsine has been supposed to be the active principle in digestion. It is contained in the cells composing the walls of the gastric glands. It is soluble in cold and lukewarm water; the solution is troubled by boiling, and then loses its digestive property. It is insoluble in alcohol and æther. Its aqueous solution is precipitated by alcohol, tannic acid, diacetate of lead, and slightly by bichloride of mercury and protochloride of tin; but not by potash, ammonia, alum, nor ferrocyanide of potassium, even in the acidified solution. A drop or two of the mineral acids causes a precipitate, which is redissolved by excess. On incineration it leaves an ash, consisting of carbonate and phosphate of soda, lime and a trace of iron.

Pepsine may be obtained by treating the mucous membrane of the stomach with water and digestion at 90°. At the end of some hours the fluid is poured off, the membrane again washed and treated with cold water until a putrefactive odour is perceptible; it is then filtered, treated with acetate of lead, the precipitate decomposed by sulphuretted hydrogen,

* I must refer the reader to an interesting paper on this subject by MM. Bernard and Barreswil (Comptes Rendus, Dec. 9, 1844, and Chem. Gaz., vol. iii. p. 41), in which it is considered as proved that the acidity of the gastric juice is caused by free lactic, and not hydrochloric acid. These experiments do not however appear to me free from fallacy.

the filtered liquid evaporated to a syrup, and the pepsine precipitated by alcohol.

According to Vogel's analysis it consists of,—carbon, 56·723; hydrogen, 5·666; nitrogen, 21·088; and oxygen, 16·523. Thus differing essentially from all the proteine compounds.

The gastric juice may be analysed in the ordinary way, if it be required merely to ascertain its general composition. Methods for separating particular constituents may be found under the heads of those substances. The compounds of most interest, occurring in it either constantly or occasionally, are the free muriatic acid, pepsine, albumen, acetic, butyric and uric (?) acids, sugar, bile and urea.

It appears that the organic principle of the bile is very speedily removed from the stomach when bile has been poured into that viscus, the colouring matter being left. In "bilious" vomited fluids I have failed to detect it, although the colouring matter was abundant, and the fluid had a bitter taste. The quantity present, if any, was too small to be appreciable by Pettenkofer's test.

Microscop. char.—There are none by which this fluid might be distinguished. If the digestive process be a kind of fermentation, either microscopic fungi or animalcules must exist in it, for no fermentation can occur without either one or the other. They have been found in the stomachs of minor animals, and exist frequently, if not constantly, in the human stomach.

The fluid lubricating the intestinal canal has been but little examined, on account of the difficulty of

obtaining it. That in the duodenum does not appear to differ from the gastric juice; it is acid during digestion, but nearly neutral when the intestine is empty. That in the large intestine is alkaline, except in the cæcum, where it is acid*.

75. Pancreatic fluid.—Little is known of this liquid. From its examination in animals, it appears to be acid when first secreted, transparent and mucous, containing a large quantity of free albumen (?), but no sulphocyanic acid. Krause found the human fluid transparent and neutral. Acetic acid caused a whitish precipitate and partial coagulation, which was increased by the application of a gentle heat. It contained minute, spherical, transparent globules, some of which were colourless, others yellowish. They varied in size from the $\frac{1}{1060}$—$\frac{1}{400}$th of a line in diameter averaging the $\frac{1}{802}$. It has been observed that a solution of chlorine coloured the pancreatic fluid of a dog bright rose-red, and at the end of 12 hours violet flakes subside. Should this be proved to occur with the human fluid, it might be of the greatest service in enabling us to detect irritation, or other disorder, inducing increased secretion of the pancreas.

76. Bile.—Although this fluid has been repeatedly examined by many excellent chemists, the present opinions regarding the nature of its main constituent are so conflicting, that it is impossible to give any very satisfactory account of it. This arises from two causes,—the facility with which the biliary matter is decomposed, and the absence of organic analyses

* Berzelius.

of several of the compounds obtained from it, whether products or educts. The mass of evidence seems decidedly in favour of its being constituted by one simple electro-negative body combined with the base soda, and mixed with colouring matter, &c. But as there is still some doubt on the point, I shall describe those substances which are obtainable from it, and some of which Berzelius considers to be true educts.

The bile is a brownish-yellow fluid tinged with green; its taste is bitter, and subsequently sweet; specific gravity about 1026; it is not coagulated by heat; is neutral when fresh, speedily becoming alkaline and decomposing; this is prevented by the removal of the mucus, of which it contains a large quantity; it may be accomplished by filtration through linen, inspissation by evaporation, and the addition of alcohol, which dissolves the biliary matter but leaves the mucus; or, more perfectly, by the addition of dilute acetic acid. On digesting the alcoholic solution with animal charcoal and evaporation, it leaves a residue, which is colourless, or nearly so, and soluble in alcohol and water but not in æther. This is the pure biliary matter, which is called bilic acid. Its aqueous solution is not precipitated by acetic acid, but is by the mineral acids, a milkiness and a syrupy liquid separating either immediately or after some time. On the addition of basic acetate of lead to the liquid, the biliary matter is precipitated, a quantity of organic matter, corresponding to the somewhat soluble lead compound, alone remaining in solution*. The alcoholic solution is not precipitated by acetate

* Liebig.

of lead* ; the aqueous is so, and acetic acid being set free, part of the lead compound is dissolved by this. The portion of biliary matter thus retained in solution was considered by Gmelin and Berzelius as a distinct substance (biliary sugar and biline), but it is nothing more than pure bile†.

When incinerated, pure bile left 6·6 per cent. of soda and 1·87 per cent. of chloride of sodium; and on organic analysis it yielded,—carbon, 68·80; hydrogen, 10·40; nitrogen, 3·44; oxygen, 17·36‡.

M. Platner has obtained some curious results with the pure biliary matter. He considers that it is composed of two distinct substances, one of which, the main constituent, may be obtained in a crystalline state. This was accomplished by evaporating the bile to dryness, adding absolute alcohol, filtering the solution, and repeating this process several times. Excess of æther was then added to the strong alcoholic solution, and the mixture set aside in the cold; the principal and most important constituent of the bile then crystallized§; from $\frac{1}{4}$–$\frac{1}{6}$ of the bile used however did not crystallize, but remained liquid. Liebig considers the crystals as bibilate of soda; they have a slightly sweetish and bitter taste, are very soluble in alcohol and water and very deliquescent. Their solution is neutral, but the deliquesced crystals are acid, this reaction disappearing on the addi-

* If the colouring matter and fat have not been separated, a slight precipitate of biliverdine and fatty acids, combined with oxide of lead, subsides.

† Liebig. ‡ Kemp.

§ These crystals, as I obtained them, formed delicate, silky, flattened needles, mostly arranged in aigrettes.

tion of water. The acid solution is not precipitated by acetate of lead, but is so when neutralized; sub-acetate of lead and nitrate of silver cause white precipitates in the acid solution; muriatic, sulphuric and nitric acids, even when concentrated, cause no opacity. When warmed, muriatic acid causes the solution to become opake, and deposit oily drops. The oily body is entirely soluble in water. After removing the crystals, if the æther be distilled, a body remains, which behaves exactly like Gmelin's biliary resin. As this crystalline compound has not been subjected to organic analysis, we are still uncertain as to its nature and relations. In the bile of the minor animals, the composition of the bilic acid seems to be constant; this would tend to render it probable that the bilic acid is a simple body, and not composed of several proximate constituents.

Berzelius, as we have stated, regards the bile as a much more complex fluid. The substances which he considers as entering into its composition will now be briefly described, with some decided products of decomposition of the bilic acid. The former are prepared as follows:—The bile is evaporated to dryness in the water-bath, or *in vacuo* over sulphuric acid, and the temperature finally raised *in vacuo* to 212°. The dried residue is powdered, and exhausted with anhydrous alcohol; mucus, chloride of sodium, and other salts and animal matters are thus left undissolved. The solution contains bilate of soda, alkaline oleate and margarate, colouring matter, &c. It is filtered, and shaken in small quantities at a time with chloride of barium, whereby a green precipitate is

formed; this consists of biliverdine and baryta. It is washed with alcohol and water, then decomposed whilst moist by dilute muriatic acid, which removes the baryta. The remaining biliverdine is then dissolved out by alcohol, and is left on its evaporation*.

If barytic water be added to the solution of bile from which the last compound has been separated, a precipitate of bilifulvine forms in combination with baryta. This is washed with alcohol and water. The latter dissolves out most of the bilifulvine and baryta, leaving a little biliverdine and baryta undissolved†.

The excess of baryta is now precipitated by carbonic acid, and sulphuric acid diluted with alcohol added as long as any precipitation of sulphates occurs. The filtered fluid is mixed with moist carbonate of lead; this removes the sulphuric and some fatty acid; excess of lead is precipitated by sulphuretted hydrogen; the solution is then filtered and evaporated to dryness. When dried, the residue is exhausted of fat by æther, and consists of biline mixed with a little fellinic and cholinic acids, resulting from its partial decomposition. The latter are removed by gradually adding a little finely divided oxide of lead in small portions; a plastery mass is formed; the solution is filtered, evaporated to dryness, and treated with anhydrous alcohol, which dissolves the biline; the solution should be evaporated *in vacuo*‡.

77. The colouring matter cannot be obtained from the bile in an absolutely pure state. It is almost insoluble in water and alcohol. It is called cholepyrrhine by Berzelius, and is remarkable for the series of

* See 78. † See 79. ‡ See 80.

tints through which it passes when treated with nitric acid, becoming first brownish, then green, blue, violet, red, and finally yellow or yellowish-brown. It is sometimes suspended in the bile in the form of a yellow powder; at others, enters into the composition of biliary calculi. It is readily soluble in a solution of caustic alkali; the solution yields a green precipitate when treated with muriatic acid. Two other colouring substances are described by Berzelius, which will be next noticed; but whether they are products or educts of the cholepyrrhine is not known. It is highly probable that these colouring matters are mere modifications of one and the same.

78. Biliverdine is insoluble in water, slightly soluble in alcohol, the concentrated solution being reddish; also slightly soluble in æther, colouring it red. Sulphuric and muriatic acids dissolve it with a green, and acetic acid with a red colour; æther colours it red. Nitric acid in excess decomposes it, rendering the solution yellow, but not causing the formation of the series of tints, except it be dissolved in an alkaline solution. It has been analysed by Scherer, who separated it from the urine of a jaundiced patient by chloride of barium. He found it composed of,—carbon, 67·761; hydrogen, 7·598; nitrogen, 6·704; oxygen, 17·937.

During the occurrence of these changes in colour, the substance loses carbonic acid and hydrogen.

79. Bilifulvine has been but little examined. It is best obtained by exhausting the dried bile first with anhydrous alcohol, and then with warm spirit (0·843). On mixing the latter solution with anhy-

drous alcohol, it is precipitated, the alcohol is distilled off, the bilifulvine dissolved in water, and the solution precipitated with acetate of lead, the precipitate decomposed by sulphuretted hydrogen, and the filtered liquid evaporated to dryness; the residue dissolved in a small quantity of water, and anhydrous alcohol added to it as long as it occasions a precipitate. This is dried, and is bilifulvine, a compound of bilifulvic acid and soda. When treated with nitric acid, the bilifulvic acid is precipitated. It is insoluble in water and alcohol*.

80. Biline (Gmelin's biliary sugar, Thenard's picromel) is colourless or pale yellow, bitter and sweet, soluble in water and alcohol, but not in æther. It may be heated above 212° without decomposition. Its aqueous solution is unprecipitated by acids, alkalies and metallic salts. It forms a semifluid compound with potash, and leaves no ash† on incineration. The mineral acids decompose it into fellinic and cholinic acids, dyslysine, taurine and ammonia. Its ready decomposition forms a marked peculiarity. In whatever manner it is procured, it always contains sulphur‡.

Biline may be obtained either by the process above mentioned, or the following:—Fresh bile is acidified with a few drops of acetic acid; neutral acetate of lead is then added; the biliverdine, oleate and margarate of lead are thus precipitated; basic acetate of lead is then added to precipitate the bilifellinic acid; the plastery precipitate is separated by filtration, and

* Löwig.

† Theyer and Schlosser obtained a strongly alkaline ash.

‡ Lehmann.

the filtered solution decomposed by excess of carbonate of soda; the precipitate is then exhausted with absolute alcohol, and the alkali thrown down from this solution by dilute sulphuric acid, cautiously added; on evaporating the alcoholic solution to dryness, the biline is left.

Liebig considers that the substance called biline is nothing more than pure bile, held in solution by the acetic acid set free on treating the bile with acetate of lead, as nearly the whole of the bilic acid is precipitated by the basic acetate of lead.

81. Fellinic acid appears to be nothing more than a combination or mixture of cholinic with choleic acid *. It is formed by digesting biline or purified bile with dilute muriatic acid for some time. At first an oily fluid (bilifellinic acid, α) separates; the digestion is continued until water, which has been poured on the residue of the decanted fluid, ceases to be rendered turbid, when a little of the latter is added to it. The separated mass is then washed with warm water, the water being subsequently added to the acid; it contains taurine and chloride of ammonium. (If the soda has not been removed from the bile, it also contains chloride of sodium.) The residuary mass consists of fellinic and cholinic acids, and dyslysine †. The two former are removed by cold alcohol (0·84), in which they dissolve; the dyslysine remains insoluble. The solution is mixed with several volumes of water, and set aside for some hours. A precipitate, consisting principally of cholinic acid, is formed, but the liquid does not

* Liebig. † Demarçay's choloidic acid.

become clear. The fellinic acid principally remains in solution. The precipitate is treated with solution of carbonate of ammonia; this dissolves the fellinic acid, leaving an acid cholinate of ammonia undissolved. The first fellinic solution is evaporated to a syrup, and also treated with the carbonate of ammonia. The ammoniacal solutions are then evaporated to dryness, the residue digested with water, and the solution decomposed by muriatic acid. The acid separates in white flakes. It is but little soluble in water, more so in æther, and readily in alcohol. It leaves no ash. Its alkaline salts form white plastery precipitates with salts of baryta. It contains no nitrogen*. It combines with biline to form—

82. Bilifellinic acid.—This exists in two forms,—one, α, containing a maximum, the other, β, a minimum of biline. The latter is obtained from the bile which has been purified from mucus, colouring matter, and other acids, with acetate of lead, by precipitation with the basic acetate. It falls in flakes, which form a plastery mass. It is separated by decomposing the lead salt with carbonate of soda at a gentle heat; and the soda salt, by sulphuric acid. It may be purified from sulphuric acid by carbonate of lead, and from fellinic and cholinic acids by æther. It forms a syrupy acid liquid, is bitter, readily soluble in hot alcohol, little so in cold, as also in hot water. It is Demarçay's choleic acid†.

* Since purified bile affords no precipitate with either barytic water or chloride of barium and ammonia, fellinic acid does not exist in it.

† Berzelius.

The bilifellinic acid α is decomposed by oxide of lead into bilifellinic acid β, biline being set free; it is unaffected by æther. The bilifellinic acid β is resolved by æther into bilifellinic acid α, fellinic and cholinic acids; the latter are dissolved by the æther, the former is insoluble.

83. Taurine is obtained in the process described for procuring fellinic acid. The solution is evaporated to dryness, the residue treated with alcohol (0·84); this dissolves the muriate of ammonia and chloride of sodium, leaving the taurine in white crystals. These are six-sided prisms, with four or six-sided summits, soluble in water, but little so in alcohol. Taurine is neutral, and not precipitated by acids nor metallic salts. It consists of $C^4\ H^7\ N\ O^6\ S^2$, yielding C 19·19, H 5·59, N 11·19, O 38·39, S 25·59; the numbers found were C 19·34, H 5·67, N 11·19, O 38·00, and S 26·00. No indication of the presence of the sulphur is obtained by boiling taurine with potash and oxide of lead*; it is however by the method recommended in 30, the only safe test of the presence of sulphur.

84. Dyslysine is obtained in the preparation of fellinic acid. It resembles resin; is but little soluble in alcohol even when boiling; the latter solution deposits an earthy powder on cooling; it is insoluble in water.

85. Cholinic acid is obtained by decomposing cholinate of ammonia (81) with dilute muriatic acid. It separates in white flakes, which when dry are readily pulverized. It is insoluble in water, soluble

* Dr. Garrod.

in alcohol, but little in æther. It differs from fellinic acid by swelling in alkaline carbonates, without however dissolving either in them or in water subsequently added. Its barytic compound is insoluble in water*.

86. Cholic acid is obtained by boiling biline or the alcoholic solution of the bile with potash as long as ammonia is evolved; the liquid is evaporated, the residue dissolved in water and decomposed by acetic acid. It crystallizes in needles, is slightly soluble in water, readily so in alcohol. It is composed of $C^{42} H^{36} O^{10}$. The cholates are mostly soluble in water, and possess a sweet taste.

87. Choleic acid.—Demarçay obtained this substance from bile by dissolving the alcoholic extract in water, and precipitating with acetate of lead, the free acid being neutralized by ammonia. The plastery precipitate is washed and boiled with alcohol; this dissolves what Demarçay supposes to be an acid salt, leaving a basic one. The lead is removed by sulphuretted hydrogen, and evaporated to a syrup, treated with æther, and then completely dried. It forms a spongy, very bitter mass; is insoluble in æther, readily so in alcohol and water. Demarçay considers it as the principal component of the bile. Berzelius regards it as his bilifellinic acid β†.

It is composed of C 21, H 36, N 2, and O 12. It contains an undetermined amount of sulphur‡.

* The non-precipitation of the pure bile by the addition of either barytic water or chloride of barium and ammonia, proves that it does not pre-exist in the bile.—*Liebig.*

† Lehrbuch, vol. ix. p. 260. ‡ Dr. Garrod.

88. Choloidic acid is obtained in the form of a solid deposit, by boiling bile with excess of muriatic acid. It is yellow and bitter, readily soluble in alcohol, but little in water, and almost insoluble in æther. Berzelius considers this as a mixture of fellinic and cholinic acids with dyslysine.

As we have stated, it is uncertain how many of these compounds are present in the undecomposed bile. The composition of the bile, according to Berzelius's view, may be stated thus:—

1. Water.
2. Mucus.
3. Colouring matter:—Cholepyrrhine { Biliverdine (bilifulvine).
4. Fatty matter { Fats:—Seroline, cholesterine, phosphorized fat. Soaps:—Alkaline oleate and margarate.
5. Biline, bilifellinic and cholinic acids.
6. Salts:—Chloride of sodium.
7. Bases:—Soda (trace of oxide of iron).

In a quantitative proximate analysis of the bile, Berzelius obtained—

Biline, fellinic acid, fat, &c.	8·00
Mucus	0·30
Alkali (which was combined with the biline, fellinic acid, &c.)	0·41
Chloride of sodium and extractives	0·74
Phosphates of soda and lime, and a trace of an animal matter insoluble in alcohol	0·11
Water	90·44

89. The method of detecting the biliary colouring matter has been already described. In an albuminous fluid, the green colour which it imparts to the albumen, precipitated by nitric acid, is evident when a minute quantity only is present. In some cases I have seen the liquid coloured greenish-yellow by

nitric acid, when the albumen remained perfectly white. Sometimes the reaction may be made evident by treating the fluid or solid with solution of potash prior to the application of the acid.

The detection of the bilic acid is described at p. 88. It does not however appear to occur in animal fluids*. When suspected, it may be precipitated by basic acetate of lead, the supernatant liquid decanted, the precipitate decomposed by digestion with a little dilute sulphuric acid, and the resulting fluid poured off, and subjected to the reactions of Pettenkofer's test.

90. The quantitative analysis of the bile may be effected either by estimating the bilic acid as a simple substance, or separating the bilic acid and biline.

For the former purpose, it should be dried in a water-bath or *in vacuo*, the residue pulverized and exhausted with æther, and subsequently with anhydrous alcohol, and digested for 12 hours with animal charcoal; the solution is filtered, evaporated to dryness, and the residue incinerated. The loss indicates the amount of bilic acid; the residue consists of carbonate of soda†.

The second method requires the separation of mucus by filtration and alcohol, and of the colouring matter by animal charcoal. The bilic acid is then precipitated by slight excess of basic acetate of lead. The fluid is gently warmed and filtered. The precipitate consists of chloride of lead, and corresponds to the chloride of sodium which was dissolved in the

* Of course excepting the bile.

† With chloride of sodium, if absolute alcohol has not been used.

alcohol. The latter is then evaporated, the residue washed with water, dried and weighed; it is bilate of lead. By incineration, the amount of base may be ascertained. The biline is obtained from the filtered liquid by decomposing the remaining lead with sulphuretted hydrogen. The solution is filtered, evaporated, the residue dissolved in alcohol, and the soda precipitated by sulphuric acid, again filtered, and the excess of acid separated by acetate of lead. The lead is then removed by sulphuretted hydrogen, the filtered solution contains the biline and acetic acid. The latter is removed by evaporation*. Or the biline, mixed with the acetate of soda, may be dried and then incinerated; the resulting carbonate of soda corresponds to the acetate, and the difference between the weight of the dried extract and the acetate of soda, calculated from the carbonate, is equal to the biline. The amount of mucus is ascertained by incinerating the portion at first left undissolved by the alcohol; it corresponds to the loss.

The microscopic appearance of the bile presents nothing characteristic. It is not uncommon to find minute amorphous particles of the colouring matter diffused through it. The mucus appears to resemble that of most other mucous membranes.

91. Biliary calculi are generally composed of either inspissated bile, cholesterine, or a mixture of the two; they frequently also contain the mucus of the gall-bladder. They are usually lighter than water, and may be analysed as follows:—They should

* Löwig.

be first powdered, and the dried bile extracted by water. The powder is next exhausted with æther, which removes cholesterine and other fatty matters; these may be separated by solution in boiling alcohol, which deposits cholesterine on cooling. The remaining powder is then treated with boiling alcohol, which removes fellinic, cholinic acids, &c. if present. The colouring matter is then removed by solution of carbonate of ammonia; potash subsequently dissolves mucus or proteine compounds; the latter may be separated by excess of acetic acid, in which they dissolve, leaving the mucus insoluble. The process will however require to be varied according to circumstances. Copper has been found in those calculi which contain any amount of colouring matter.

92. Excrement.—The excrementitious matters forming the fæces have been elaborately examined by the indefatigable Berzelius, upon whose process I shall base my observations; the method pursued may be also well applied for their general examination.

When fæces are mixed with water, well-stirred and set aside, one part dissolves, another remains insoluble. By filtration through linen, these are separated; the insoluble portion is composed of undigested substances. The liquid part is allowed to repose, and filtered through paper; an insoluble part (B) remains, a soluble (A) passes through.

If a portion of the fluid be set aside, ammonia is formed, and a scum of crystalline triple phosphate is found on the surface. If the solution be evaporated by a gentle heat to the consistence of a thin extract, and then treated with alcohol, this dissolves one por-

tion (α), acquiring a reddish-brown colour, whilst a grayish-brown matter is separated (β).

1. When the alcoholic solution is mixed with a little water, the alcohol distilled off, and a little sulphuric acid added, a brownish precipitate falls, more of which is formed on evaporating the solution. This is composed of bilifellinic acid, α, and may be resolved into biline and bilifellinate of lead by oxide of lead, but the biline is very brown.

If the mixture be distilled with sulphuric acid, a liquid containing no acetic acid, but a trace of muriatic acid, passes over; and if, after the separation of the biliary resin, the sulphuric acid be neutralized with carbonate of lime or baryta, the solution evaporated, and the residue treated with alcohol, sulphate of lime or baryta is left, and a reddish-brown extractive matter is dissolved, which remains transparent after the evaporation of the alcohol. It is soluble in water and alcohol; the first solution is reddened by acids, and is almost completely precipitated by tin, lead and silver salts, also by tannic acid. It contains some alkali, and appears to be the cause of the alteration in the colour of the solution on exposure to the air.

2. That portion of the excrements soluble in water left, as we have seen, a certain quantity of substance insoluble in alcohol, consisting principally of albumen coloured brown by bile, and alkaline sulphate and phosphate, which are left on incineration.

3. The portion of the excrement (B) consists of intestinal mucus, and the matters precipitated by the bile. It is very "mucous." It swells in water,

is soluble in caustic potash, and re-precipitated by acids, the fluid evolving an odour of bile.

Alcohol and æther extract fat and bilifellinic acid (α) from it. The fat, removed by æther, is dissolved by caustic potash. After it has been treated with alcohol and æther, a matter is dissolved by warm water, which colours it yellow; on evaporation, it leaves a brownish extractive mass, which does not again completely dissolve in water. It is insoluble in alcohol; its solution is troubled by diacetate of lead and tannic acid; the latter disappears by heat. By the continued action of alcohol or æther and water, more biliary resin and matter soluble in water can be removed; but finally an insoluble mass remains. This is probably intestinal mucus coloured by biliary colouring matter, and is soluble in caustic potash. Dried excrement yields about 0·15 per cent. of ash, consisting of phosphate of lime with phosphate of magnesia, and a trace of sulphate of lime, 0·1; carbonate of soda, 0·008; sulphate and phosphate of soda, with a little sulphate of potash and silica, 0·018.

Berzelius obtained by analysis—

Water		75·3
Soluble in water...	Bile	0·9
	Albumen	0·9
	Peculiar extractive	2·7
	Salts	1·2
Insoluble residue of food		7·0
Matters added by the intestinal canal and its appendages, as mucus, biliary resin, fat and peculiar extractive		14·0
		100·0

The salts, extracted by water from 3 oz. of fresh fæces, Berzelius found thus constituted:—

Carbonate of soda	3·5
Chloride of sodium	4·0
Sulphate of soda	2·0
Phosphate of lime	2·0
Phosphate of magnesia	4·0
	15·5

93. The examination of the fæces, both in health and disease, although certainly a most unpleasant task, is undoubtedly more important than that of any other excretion, and will certainly throw great light on many points both in physiology and pathology. We have lately learned that the bilic acid and the colouring matter of the bile have no essential connexion with one another, and that the detection of the one does not permit of our drawing any conclusion as to the presence or absence of the other. The bilic acid appears to be very rapidly removed from the intestines; and although the colour of the fæces may have the normal depth of tint, there is generally barely more than a trace of the bilic acid to be detected. The two however are apparently secreted in certain tolerably definite proportions; so that, by the appearance of the one in the fæces, we may judge with tolerable accuracy of the probable amount of the other, which has been secreted, but has disappeared from absorption. We are unacquainted with the causes of the variation in the colour of the fæces, exclusive of the depth of normal tint dependent upon the presence of the colouring matter of the bile in greater or less quantity. The changes seem however principally to occur after the bile has been poured into the intestine*; for that fluid, in ordinary cases,

* I believe that great benefit would arise in practice from attention to this suggestion.

differs remarkably little from its normal characters, judging from its appearance in the gall-bladder, as discovered by *post mortem* examinations. In some cases, especially diarrhœa, the bilic acid seems to occur in the fæces in considerable abundance. The principal abnormal constituents of the fæces are fatty matters, sometimes in great abundance; undigested portions of food, particularly vegetables*; sugar; free albumen; fibrine, or the oxides of proteine, in the form of false membranes, sometimes representing casts of the intestines; urea; increased quantity of mucus; the earthy phosphates, either crystalline or amorphous; blood; alkaline salts, and the various ordinary products of putrefactive fermentation, necessarily accompanying which are infusoria.

After the use of mercury as a purgative, the motions are green, especially in children; this arises from the presence of an increased quantity of the biliary colouring matter, the corresponding bilic acid being also present in greater proportion than natural. Simon obtained from 100 parts of the dry residue—

Green fat, containing cholesterine		10·00
Substance resembling ptyaline, soluble in water only, and but slightly precipitated by tannic acid and acetate of lead		24·30
Biline, with bilifellinic acid and biliverdine, together dissolved by anhydrous alcohol		21·40
Extractive soluble in dilute alcohol		11·00
Albumen, mucus, and epithelial cells		17·10
Salts		12·90

Calculi are sometimes formed in the alimentary canal; they usually consist of undigested portions of

* The microscope is of infinite service in unmasking the nature of these substances.

the vegetable food, as the hairs on the oat, &c. They are best recognised by the microscope.

94. Milk.—The ordinary appearances of milk are too well known to require description. It is slightly alkaline; spec. grav. about 1030. Its opacity is caused by a very large number of oily globules. When perfectly dried, it leaves 10–15 per cent. of residue, and on incineration yields 0·1–0·25 per cent. of ash, one-third of which consists of soluble salts. It is coagulated by acetic, lactic, and most dilute acids, as also rennet. After having been coagulated by rennet or lactic acid, the filtered solution is coagulated on ebullition. The substance thus precipitated has been considered as albumen, and denominated *zieger*; it is however nothing more than caseine. When set aside, a white scum gradually forms on its surface, constituting the cream; this is composed of the light globules, a small portion of caseine, and a little serum, retained interstitially by the globules. The spec. grav. of cream is about 1024. By churning, the globules are beaten into union, and butter is formed. The fluid which remains is butter-milk. Butter consists of stearine, elaine and butyrine; it is easily saponified, yielding 88·5 per cent. of fatty acids combined with glycerine; these consist of stearic, oleic, capryllic, and capric with butyric and caproic or vaccinic acids. Many of these substances have been described; those which are peculiar to the milk will now be noticed.

95. Caproic acid is a volatile fatty oil, which remains fluid below 16°, boils at a temperature above 212°, has an odour resembling that of perspiration

and dilute acetic acid, is but little soluble in alcohol and æther, readily so in anhydrous alcohol. Its barytic salt crystallizes in long silky needles, which are aggregated into bundles, anhydrous, and unchanged by exposure to the air. Caproic acid consists of $C^{12} H^{11} O^3$ *.

It may be obtained in the same manner as butyric acid, from the caproate of baryta (p. 27), which must be purified by recrystallization.

96. Capric acid is volatile and fluid, solidifies at 5°, boils above 212°, and is but little soluble in water and æther. It is composed of $C^{20} H^{19} O^3$.

Its barytic salt is very difficultly soluble, anhydrous, unaffected on exposure to the air, and crystallizes in needles and scales. Chevreul's caprate of baryta consists of two distinct salts, the true caprate and the capryllate.

Capric acid may be obtained from the caprate of baryta (p. 27). This exists in the saline mass which remains undissolved in the first portion of water (p. 27), and is separated by dissolving it in as much boiling water as is requisite for perfect solution and filtering whilst hot. On cooling, caprate of baryta subsides in minute scales. More is obtained on the further evaporation of one-fourth of the liquid. It is purified by recrystallization.

97. Caprylic acid forms a greasy mass, crystallizes below 50°, and is difficultly soluble in water. It is composed of $C^{16} H^{15} O^3$.

Its barytic salt is anhydrous, permanent, does not fuse at 212°, and is very sparingly soluble in water.

* Lerch, Chem. Gaz., vol. ii. p. 379.

The capryllate of baryta remains in the mother-liquor from which the caprate of baryta has subsided; by spontaneous evaporation and re-crystallization it is obtained pure.

It has been stated above, that on the saponification of butter, instead of butyric and caproic acids, we sometimes obtain another, having the same saturating capacity as the two former conjointly, but probably containing less oxygen; this is

98. VACCINIC ACID.—It has not been perfectly examined.

Its probable composition is $C^{20}\ H^{18}\ O^{5}$; it is a bibasic acid.

Its barytic salt is efflorescent, has a strong odour of butter, is of about the same solubility in water as the butyrate of baryta, and contains an undetermined amount of water. Vaccinic acid is readily decomposed into butyric and caproic acids.

99. SUGAR OF MILK has a slightly saccharine taste.

Chem. prop.—It is soluble in 6 parts of cold, in 3 parts of hot water; is insoluble in absolute alcohol and æther, but dissolves in dilute alcohol in greater proportion as its strength is less. By the ebullition of its solution with dilute muriatic, sulphuric or acetic acids, it is converted into grape-sugar. When strongly heated it fuses, gives off 11·9 per cent. of water, and solidifies into a crystalline mass on cooling. Fixed alkalies convert it at a high temperature into oxalic acid. Its aqueous solution is not precipitated by bichloride of mercury, tannic acid, nitrate of silver, nor either acetate of lead; but it is so by strong alcohol;

the sugar falls in a crystalline state. With strong nitric acid it yields saccharic, mucic and oxalic acids. On incineration it leaves 0·1–0·4 per cent. of ash, consisting of phosphate of lime. It ferments difficultly with yeast and produces alcohol, mucous sugar being formed at the same time; this fermentation probably ensues in mucous or grape-sugar which is formed from the milk-sugar, by the action of the lactic acid produced.

It consists of $C^{12} H^{10} O^{10} + 2HO$; yielding carbon, 40·46; hydrogen, 6·60; and oxygen, 52·93.

It exists in human milk, forming about 4·7 per cent., or two-fifths of the solid residue; and yields the same reactions with Trommer's and Pettenkofer's tests as the grape or diabetic sugar.

Microscop. char.—It forms four-sided prisms when slowly crystallized, otherwise the curious forms figured in Pl. IV. fig. 23.

The following are the components of milk:—

1. Water.
2. Caseine.
3. Fatty matters. { *Neutral*, elaine, stearine, butyrine. *Acid*, elaic, stearic, butyric, capric, caproic, capryllic or vaccinic. *Basic*, glycerine.
4. Extractives.
5. Salts. { *Alkaline*, muriates and phosphates of potash, soda and ammonia with soda. *Earthy*, chloride of calcium, phosphate of lime and magnesia.
6. Trace of oxide of iron.
7. Sugar.

The ash of evaporated milk yields alkaline sulphate, a product of the oxidation of the sulphur of the caseine combined with soda and potash.

100. The analysis of milk is difficult, on account

of the caseine being somewhat soluble in the reagents ordinarily used in the analysis of organic fluids, especially when mixed with salts.

The following is that of M. Haidlen, perhaps the best :—

Burnt gypsum is moistened with water, so as to allow of its combination with its water of crystallization, gently dried, finely powdered, and again dried in a water-bath. One-fifth part of this by weight is then boiled with the milk, the whole evaporated to dryness in the water-bath, and weighed; the weight of the residue *minus* that of the gypsum is equal to that of the solid contents. These are then powdered in a warm mortar*, and the powder put into a weighed flask; the weight is then again taken, and the powder is treated with æther, until all the fat is removed, dried at 212° in the flask and weighed. It is then digested with boiling alcohol (0·85), placed on a weighed filter and well washed with alcohol. The residue is the caseine with the sulphate of lime, the sugar and soluble salts being dissolved by the alcohol. By deducting the weight of sulphate of lime from that of the residue, the weight of the caseine is obtained. The salts may be separated from the sugar by incineration; but their analysis is best made from a separate portion.

The following analyses may be regarded as expressing the average composition of milk :—

* The quantity used for the second operation must be weighed, and the result calculated for the residue.

	Human.		From the cow.
Water	88·36*	89·2†	85·7*
Solids	11·64	10·8	14·3
Butter.....	2·53	3·4	4·0
Caseine	3·43	3·1	7·2
Sugar and extractives	4·82	4·3‡	2·8
Fixed salts	2·30		0·62

Haidlen obtained 0·49 per cent. of ash from cow's milk; it consisted of—

Chloride of sodium.....	0·024	0·210 soluble salts.
Chloride of potassium	0·144	
Soda.....	0·042	
Phosphate of lime	0·231	0·280 insoluble salts.
Phosphate of magnesia	0·042	
Phosphate of the peroxide of iron	0·007	

Microscop. char.—The globules of milk are of extremely various sizes, they have been figured in Pl. II. fig. 32. They have no tendency to coalesce; this arises from their being coated with a delicate layer of caseine which envelopes them, and is perfectly structureless. If a little acetic or lactic acid be added to milk, the membranes are dissolved and the fatty globules unite; they also then become readily soluble in alcohol and æther, whereas in ordinary milk they cannot be dissolved by either of these reagents. The demonstration of these coverings is a matter of great difficulty. Donné recommends that a drop of milk be placed between two pieces of glass, and that these be rubbed over each other; by this means they become ruptured and visible; I have

* Simon. † Haidlen.
‡ Sugar only.

not, however, been able to distinguish them by this, nor any other means which I have adopted; nor can I distinguish any difference in the surface of these globules and those prepared by triturating water with oil and sulphate of lime or any insoluble powder, which causes its subdivision into exceedingly minute globules. The globules appear to be rather larger in human than in cow's milk.

When milk is kept in a warm place, free lactic acid speedily forms, this precipitates part of the caseine, at the same time the minute vegetable forms, spoken of in Part I. p. 50, are found in it. After milk has been coagulated by rennet or an acid, a portion of the caseine remains in solution; this has been called zieger; it is coagulated by heat.

101. The first secreted milk or colostrum is alkaline, and differs from that which occurs subsequently, in containing more solids, fat and salts. The corpuscles in it are also different; they are of two kinds, one consisting of fat globules, which are partly larger than in the ordinary milk, and frequently coalescing; the second is composed of granulated, yellow rounded corpuscles, which are larger than those of the milk, and are apparently composed of aggregated very small fat globules. See Pl. IV. fig. 26.

102. Semen.—This fluid is always found mixed with that of the prostate gland. It is thick and viscid, having an odour somewhat resembling that of rasped bones, or a very strong solution of carbonate of soda. Before it has been retained in the *vesiculæ seminales*, it is more aqueous. The odour does not depend upon any substance dissipated by heat, for

on moistening the dried fluid it is again perceptible. It is slightly alkaline, and coagulated by heat, nitric acid and the ordinary tests for albumen. Vauquelin found that semen spontaneously deposited crystals of phosphate of lime. I have some of these obtained from dried semen; they were undoubtedly composed of phosphate of lime; they are figured in Plate IV. fig. 29.

When dried, semen leaves about 10 per cent. of solids; Vauquelin found these composed of peculiar extractive 6·0, phosphate of lime 3·0, and soda 1·0.

Semen contains a remarkable mucoid substance, which does not appear to be in solution but suspension; some time after the fluid has been emitted this substance gradually dissolves, and the solution is no longer coagulated by heat*. It is soluble in acetic acid, and the solution is precipitated by ferrocyanide of potassium. It has been called spermatine. If the semen be put into water at once, it does not dissolve, but forms a fibrous coagulum. The fresh semen is dissolved by all acids, even the uric and tartaric, and alkalies cause no precipitate in the solution.

Microscop. char.—The semen mixed with the prostatic fluid (as it ordinarily occurs) contains five different kinds of bodies:—α, the spermatozoa, which are figured in Pl. IV. fig. 29; β, mucous globules, usually very large and distinct; γ, some of a whitish-yellow colour, not half the size of the last, and having neither a granular surface nor a nucleus; δ, the ordinary organic molecules; and lastly, epithelial scales.

* Berzelius.

We rarely have the opportunity of examining the seminal fluid, and when presented to us, it is generally in the dried state. The spermatozoa are the readiest objects by which it can be detected, but these are not invariably present. When semen is mixed with the urine, the latter becomes slightly albuminous, and the spermatozoa may be found in the deposit. If the deposit, or any fluid suspected to contain these animalcules, be allowed to evaporate nearly to dryness, they may frequently be much more readily detected than by the ordinary method.

103. Tears.—The fluid of which these are constituted is alkaline, mucous and watery. On evaporation it leaves about 1 per cent. of solid residue; this consists principally of chloride of sodium and ammonium, with a yellowish extractive matter not completely soluble in water, and a small quantity of soda.

On microscopic examination it exhibits mucous corpuscles, organic granules and a few epithelial scales.

104. Perspiration.—The history of this important fluid is very imperfect. It does not differ materially from any other dilute mucous secretion. It is slightly acid, has a spec. grav. of 1003–1004, and consists of fat, mucus, sometimes butyric, carbonic and acetic acids and their salts, chloride of sodium and ammonium, phosphate of soda and lime, and a trace of oxide of iron. Anselmino obtained from $\frac{1}{2}$ to $1\frac{1}{4}$ per cent. of solid matter. According to his analyses, the proportion of constituents in 100 parts of perspiration, yielding 1 part of solids, was

Water.....	99·00
Aqueous extractive with sulphates	0·21
Alcoholic extractive with acetates	0·29
Chloride of sodium and spirituous extractive.....	0·48
Phosphate of lime, epithelium and oxide of iron ...	0·02

The average quantity of perspiration was found by Seguin to be 11 grs. per minute, equal 33 oz. *per diem*.

Microscop. char.—It exhibits mucous corpuscles, epithelial scales and organic granules.

105. CERUMEN.—This semisolid substance is a kind of emulsion, consisting of soft fat and albumen; a yellow, very bitter alcoholic extractive matter; an aqueous extractive; soda, potash and lime, in combination with animal matter, but neither alkaline chloride nor phosphate.

The fatty matter consists of a mixture of stearine, cholesterine and oleine, and is removed by æther; alcohol then dissolves the bitter extractive, which on evaporation forms an uncrystallizable residue, the aqueous solution of which differs from the aqueous extractive of other animal fluids in not being precipitated by either lime-water, diacetate of lead, bichloride of mercury, or tannic acid. When incinerated, it leaves an ash, consisting of carbonate of soda and lime. The portion of cerumen left undissolved by æther or alcohol yields a small quantity of extract to water, which is not precipitated by lime-water, basic acetate of lead, or bichloride of mercury. That portion undissolved by æther, alcohol and water, consists of a mixture of albumen and epithelium. The former is dissolved by acetic acid, the latter being left.

With the microscope, the cerumen exhibits oily

globules, mucous corpuscles, epithelial scales, and an amorphous granular matter.

106. Amniotic fluid.—This is turbid, yellowish and alkaline, coagulated by heat, nitric acid, and slightly by acetic acid. Its spec. grav. is about 1008, yielding from 1 to 3 per cent. of solids. Bichloride of mercury causes a precipitate, which soon becomes of a rose colour. Benzoic acid and urea have been found in the liquid after it had undergone partial decomposition. It contains chloride of sodium, sulphate and carbonate of soda, sulphate of lime, with traces of salts of potash. The microscope detects mucous corpuscles with tesselated and ciliated epithelium.

107. Allantoic fluid.—This fluid has been examined in animals. Its spec. grav. was found to vary from 1003–1029. On evaporation, a brownish film forms on its surface, which gradually subsides in flakes, and consists of albumen and earthy phosphates. The residue of its evaporation is partly soluble in alcohol; the solution, on evaporation, yields an acid extractive matter and pearly crystals, which are undissolved on treating the mass with water; the latter are composed of allantoin. The fluid also contains chloride of sodium and ammonium, sulphate and phosphate of soda, phosphate of magnesia and lime, with an aqueous extractive matter. It also contains uric acid, and probably urea.

Allantoin.—This interesting substance does not occur in the human body. Its preparation from the allantoic fluid of animals has been described. It may be obtained artificially by gradually adding peroxide of lead to a mixture of uric acid with water nearly

raised to the temperature of 212°; as soon as the oxide of lead ceases to be altered in colour, no more is added. The solution is filtered whilst hot, and on evaporation it crystallizes. It may be freed from urea by cold alcohol. It is rather insoluble in water and alcohol. Its formula is $C^8 H^5 N^4 O^5 + HO$.

Microscop. char.—It forms colourless rhombic prisms.

108. Mucus.—This is a very important secretion from all mucous surfaces, the most obvious purpose of which is to defend them from the contact of irritating matters. In health it is not secreted in large quantity, but in cases of irritation of the secreting surfaces its amount is much increased and its properties considerably altered; the latter are the circumstances under which it is ordinarily presented to our notice.

When moist, it forms a gelatinous, viscid, semi-transparent mass, which sinks in water; its degree of inspissation varies; sometimes it is limpid, at others it may be drawn into long threads. When dried, it forms a yellowish mass, which swells in water, re-acquiring its former properties.

Chem. prop.—It is insoluble in water, alcohol and æther; reacts as an alkali; is coagulated or corrugated, frequently presenting a fibrous appearance when treated with acetic acid; the latter phænomenon sometimes occurs when it is mixed with much water. When mixed with water and boiled, no coagulum is formed at first, although on long-continued boiling the liquid becomes milky and yields a slight deposit. It yields little or no precipitate with nitric

acid, and is perfectly soluble in caustic alkalies. When suspended in water and the poles of a voltaic battery are immersed in it, albumen is liberated at one or both poles. On incineration, it leaves an alkaline ash, containing carbonate and sulphate of soda, chlorides of sodium and potassium, and phosphate of lime.

The composition of mucus is not satisfactorily known; the biliary mucus is the only one which has been examined; this was obtained from ox-bile. It yielded,—C 52·54, H 7·95, N 14·33, O + S 25·18*; thus approaching the binoxide of proteine in composition, or still more the buffy coat of blood.

Its properties, as stated above, vary according to the membrane by which it is secreted. The chief peculiarities are as follows:—Nasal mucus is remarkable from its great "mucosity," its property of imbibing water and swelling several times after having been dried, and its solubility in acids. It leaves 5·98 per cent. of dry residue on evaporation, and 0·65 per cent. of ash. Intestinal mucus is very viscid; when dry, it is hard and elastic; it swells in water, and if this contains a little alkali it again becomes mucous. It is dissolved by potash and reprecipitated by acids.

Biliary mucus occurs partly in solution(?) and partly in a state of suspension: on filtering the bile, the latter portion is retained, the former passing through the filter, and rendering the bile precipitable by acetic and other acids and alcohol. After treat-

* Dr. Kemp.

ment with alcohol, it does not become viscid when moistened.

Vesical mucus has been described in Part I. p. 8.

Microscop. char.—Mucus exhibits corpuscles (Pl. IV. fig. 18 *a*, and 19 *b*) which resemble those of pus, but are not so readily acted upon by acids, yielding generally a single nucleus only, and that much larger than in the globules of pus; it also contains granules of various sizes (fig. 19 *c*), some of them being mere molecules, others as large as the nuclei of the globules of pus; epithelial scales, and occasionally a fibrous structure are present (fig. 19 *d*); the fibres of the latter appear composed of very minute granules. In the centre of many of the epithelial scales, large oval granular corpuscles are visible (fig. 18); they cannot however be mistaken for the true corpuscles of mucus, as they are unacted upon by acetic acid.

109. In disease, the mucus becomes materially altered in quantity and composition; in some cases it contains less solid matter than usual, but a very large relative proportion of saline matter to the dry extract; in others, this increase is not present. The peculiar muco-purulent secretion will be noticed presently; this is almost constantly present in the latter stages of pulmonary diseases; in the secretions of other diseased membranes this peculiar secretion is more rarely observed. Diseased mucus is sometimes acid, and contains various abnormal constituents, such as true pus, blood-corpuscles, abundance of epithelial cells, fatty globules, portions of tuberculous matter, and even of the pulmonary structure

itself. Vegetable organizations, somewhat resembling the torulæ occurring in diabetic urine, are also sometimes found. Particles of starch have been found imbedded in masses of mucus; white specks of this kind must not be confounded with those formed of tubercle.

Tubercles, when examined with the microscope, exhibit aggregations of minute amorphous granules, which have vascular(?) fibres running through them, occasionally also minute fatty globules. There is no peculiar tubercle-globule*. If they have commenced to soften, lymph- or pus-corpuscles are intermixed with the granular substance. They are soluble in acetic acid and ammonia. The peculiar tubercle-globules described by Gruby are supposed by Simon to be particles of starch derived from the food. They might readily be distinguished by a little solution of iodine, or the polariscope.

When subjected to proximate analysis, tubercle yields a small quantity of fatty matter containing cholesterine and cerebric acid; a substance precipitable by acetic acid and forming a scum when heated, like caseine; albumen, and a residue insoluble in water, somewhat resembling fibrine; also salts.

On organic analysis, it presents no constant composition, as this varies according to the source from which it is derived.

From the lungs it yielded,—carbon, 53·888; hydrogen, 7·112; nitrogen, 17·237; and oxygen, 21·767; corresponding to the formula $C^{35}\ H^{29}\ N^{5}\ O^{11}$.

* Hasse describes bean-shaped or serrated cells, some smaller, others larger than pus-cells, and somewhat flattened.

Fluids secreted by Serous Membranes.—In the healthy state the quantity of fluid secreted by these membranes is extremely small, and we have no opportunity of examining it. Probably the nearest approach to the natural state of the fluid is that which is frequently found after death in the ventricles of the brain, or between the membranes of the spinal cord.

The former is limpid, almost colourless, having a spec. grav. of about 1008, containing no fibrine. The ordinary tests for albumen cause slight precipitates, but in all probability the small quantity of that substance thus indicated is derived from the passage of the fluid over the cut surface of the brain or its blood-vessels. It usually has the properties of diluted serum of the blood. Berzelius found it composed of—

Albumen	0·166
Alcoholic extractive, with soda	0·232
Alkaline chlorides	0·709
Soda	0·028
Animal matter, insoluble in alcohol	0·026
Earthy phosphates	0·009
Water	98·830

Mulder found also fatty matter and alkaline sulphate in it.

From the Cavity of the Pleuræ.—These fluids are highly interesting, but have been very imperfectly examined. They vary considerably in appearance and composition, being sometimes serous, and forming a coagulum after removal from the chest during life, at others partially or completely purulent.

Peritonæal Fluids.—These are usually of high specific gravity, containing albumen abundantly, but

not differing in the nature of their constituents from other serous fluids*.

Ovarian Fluids.—These differ remarkably in their properties, sometimes being quite limpid, and at others dark-coloured, and so thick and gelatinous as to obstruct the canal of the instrument by which they are removed. The animal matter which they contain is in many cases quite peculiar, being exceedingly viscid, and of a brownish or bluish colour; it is probably some modification of proteine. The fluids are slightly alkaline, coagulable by heat and nitric acid; the precipitate with the latter is frequently yellow. Their constituents do not differ, with the above exception, from those of the blood, except that they contain no alkaline phosphate, or at least an exceedingly minute quantity only.

Serous Fluids from the Tunica Vaginalis.—These much resemble some of those fluids found in other serous sacs. They contain however more fatty matter, are usually yellowish, slightly opake and alkaline, yielding albumen copiously. The remarkable fact, that when the fluid of hydrocele is mixed with the serum of the blood, or digested with the deposit which subsides from an admixture of blood with water immediately after its removal, a coagulum is formed, has been pointed out by Dr. Buchanan. The cause of this phænomenon and the nature of the coagulum are unknown.

* Marchand found one composed of,—albumen, 2·38; urea, 0·42; carbonate of soda, 0·21; chloride of sodium, 0·82; phosphate of soda, with traces of sulphate, 0·06; siliceous matter and loss, 0·89; water, 95·22.

The fluids of serous cavities frequently contain urea, blood-corpuscles and crystals of cholesterine, the latter floating on their surface. They may be analysed in the same manner as the serum of the blood, but particular attention should be paid to the properties of the various compounds which they contain. When examined microscopically, globules of various kinds are perceived, some much resembling those of mucus; organic granules, with blood-corpuscles, spermatozoa and crystals of cholesterine. Sometimes numerous pus-globules are visible; these are, however, in general not so perfect as in true pus, being frequently disintegrated, or partially so.

110. Pus.—Healthy pus is a yellowish, opake, neutral fluid which is coagulated by heat, alcohol and nitric acid, the globules being entangled in the coagulum. Its spec. grav. is about 1030. When mixed with water it is precipitated by acetic acid; this does not however always occur. Caustic potash converts it into a uniform, tenacious, mucous mass, in which the addition of water or of acids causes a precipitate. Ammonia acts much in the same way as potash. When pus is mixed with alcohol, and the coagulum washed with that liquid, water subsequently added dissolves a substance which was considered as peculiar to pus, and was called pyine; Mulder states that it is tritoxide of proteine. It agrees with that substance in all the properties which have been detailed (1. c, β.). It is moreover soluble in dilute alcohol, and yields precipitates with dilute muriatic and sulphuric acid and alum, which are redissolved by excess;

acetic acid causes a precipitate not soluble in excess. In addition to albumen and tritoxide of proteine, pus contains cholesterine, stearine, oleine, oleate of soda, alkaline chlorides, carbonates, sulphates and phosphates, as also earthy phosphates and oxide of iron; the latter is probably derived from an admixture of blood. The quantitative analyses of pus differ so much from each other that I shall not detail them. The amount of solids is about 10–15 per cent. The action of neutral salts, as chloride of sodium or ammonium, &c., upon pus is very remarkable. The corpuscles lose their diffusibility through water, and form a large tenacious mucoid mass, which sometimes assumes the appearance of beautiful delicate membranes; it is corrugated or coagulated by acetic acid, as also by nitric acid, and when washed with water the whole of the saline matter is not removed. When examined with the microscope the substance still more resembles mucus than in its chemical properties, being composed of the mucous corpuscles, which are but little affected by acetic acid, and the granular base consisting of irregular molecules.

Microscop. char.—Pus contains a large number of corpuscles, to which its opacity and colour are entirely due. They are spherical, granulated on the surface, contain nuclei varying in number from one to four or five, and within these nucleoli (Pl. IV. fig. 25). The cause of the granular aspect of their surface, which we also find in the lymph and mucus-corpuscles, is obscure. On treatment with acetic acid the external portions of the corpuscles are dissolved, the nuclei being left; these are generally two or three

in number. In addition to these, others, less numerous and smaller, are present, which are suspended in the liquid ; these are not granulated on the surface. There does not appear to be any essential difference between lymph-corpuscles, the colourless corpuscles of the blood, exudation-corpuscles, those in mucus, those of pus and the proper (?) chyle-corpuscles.

It is thus perceived that pus is composed of two distinct parts; one of which is liquid, the other consisting of minute cells or globules, and both these are essential to the constitution of true pus. If attention be paid to this fact there will be no difficulty in distinguishing pus from mucus. It frequently happens, however, that we meet with an excreted substance which does not yield these two constituents, but still has the general purulent appearance; it contains the granular corpuscles in abundance, these give it the peculiar colour, but the vehicle in which these are suspended is not albumen, or if any of this substance be present it is but a trace. Mucus here occupies the place of the true purulent albuminous vehicle; the limpidity of pus being exchanged for viscidity and tenacity. Hence also the substance frequently floats in water, as we sometimes find with mucus, especially that from the lungs, its viscidity enabling it to confine small quantities of air which are sufficient to render its spec. grav. less than that of water; moreover it cannot be mixed with or diffused through water like pus.

In some cases the purulent matter is much more fluid, containing few or no granular corpuscles, but numerous red corpuscles of the blood or a solution

of their colouring matter; the fluid is generally at the same time fœtid, ammoniacal, and contains sulphuretted hydrogen.

In chronic abscesses the character of the purulent matter is frequently most materially changed, no pus-corpuscles can be detected, but the whole mass appears milky and is composed of innumerable irregular granules of various sizes, none so large as the pus-corpuscle, and none containing nuclei; numerous fatty globules and plates of cholesterine are also present, the albuminous vehicle remaining the same.

111. The following is a general method for analysing various concretions:—

a. The substance is powdered, weighed and thoroughly dried, again weighed and extracted with æther, which removes fatty substances. The powder is then exhausted with alcohol, and the substances removed are separately examined.

b. The next proceeding must be varied according to the nature of the calculus; if composed principally of phosphates it is exhausted with boiling water; dissolved in muriatic or nitric acid, the solution treated with excess of ammonia, which precipitates phosphate of lime and magnesia, oxalate of ammonia subsequently precipitates the lime which was not in combination with phosphoric acid, and phosphate of soda mixed with free ammonia precipitates the remaining magnesia. This process is not perfectly accurate, as the muriate of ammonia formed retains a portion of the phosphate of lime in solution, so that on subsequently precipitating with oxalate of ammonia the lime separated is partly derived from the de-

composed phosphate. It may be modified by treating the acid solution with ammonia until a very slight precipitate is occasioned, dissolving this in a little acetic acid, then precipitating the lime with oxalate of ammonia, and the magnesia subsequently by ammonia. These precipitates may all contain animal matters, which are destroyed by incineration.

c. A third process is to precipitate the phosphoric acid in combination with iron, as in 34 *e*, subsequently the lime by oxalate of ammonia, and the magnesia by ammonia and phosphate of soda.

d. If the substance consists of carbonate or oxalate of lime it is treated with caustic potash; this dissolves animal matter, uric acid, &c.; dissolved in nitric or muriatic acid, treated with excess of ammonia to precipitate the oxalate and any phosphate*, and the lime separated by oxalate of ammonia.

e. If it consists principally of uric acid, urates, &c. The portion dissolved by water may consist of the urates of potash, soda, ammonia, lime and magnesia, small quantities of phosphates and animal matters. If the solution be evaporated almost to dryness, the urates are deposited, they may be decomposed by muriatic acid and the bases estimated. The portion undissolved by water is treated with dilute solution of potash, and the solution precipitated by acetic acid in considerable excess; the precipitate consists of uric acid. The solution is evaporated until the odour of acetic acid disappears, then treated with water, which leaves albumen, and mucus undissolved. The

* These may be separated by heating to redness, dissolving in muriatic acid, and precipitating the phosphate by ammonia.

solution in water may be tested for animal matters with infusion of galls, bichloride of mercury, chloride of tin, &c.

112. Concretions from the Air-passages.—These usually consist of a small quantity of animal matter with phosphate and carbonate of lime and a little magnesia. I found in one, animal matter (mucus with a little blood) 12·5, phosphate of lime 76·35, and carbonate of lime 10·47; it was perfectly structureless.

113. From the prostate Gland.—These have usually the same general composition as the above, the principal constituent being the phosphate of lime.

114. Gout Stones.—These are earthy-looking bodies, consisting principally of urate of soda and cellular tissue. They also contain a little chloride of sodium, sometimes urate of lime and potash. The urates of soda, potash and lime, are soluble in boiling water, the organic substance remains undissolved. Wurzer obtained uric acid 20·0, soda 20·0, lime 10·0, chloride of sodium 18·0, chloride of potassium 2·2, animal matter 19·5, and water 10·3. They may be analysed as in 6.

115. Bones may be analysed according to the methods given in 1, 2 and 3. They consist principally of gelatine, phosphate and carbonate of lime, carbonate of magnesia, fluoride of calcium, sometimes a little oxide of iron and magnesia. After incineration sulphate and carbonate of soda and chloride of sodium are found in the ash. The two former are derived from the combustion of the organic matter.

To analyse the bones they should be separated as

perfectly as possible from the periosteum and marrow, dried at a temperature of 248°–266°, so as to drive off the water; exhausted with æther to remove the fat, incinerated to destroy the organic matters, the soluble salts extracted by boiling water, and the residue treated as above (112, *b*). The fluoride of calcium is estimated according to 36.

Marchand obtained from the femur,—

Cartilage	32·25
Vessels	1·01
Basic phosphate of lime	52·26
Fluoride of calcium	1·00
Carbonate of lime	10·21
Phosphate of magnesia	1·05
Soda	0·92
Chloride of sodium	0·25
Oxide of iron, manganese and loss	1·05
	100·00

The magnesia probably exists in the bones as a carbonate, being converted into phosphate during the incineration.

The relative proportion of inorganic matters is not the same in all bones.

In the first part of this work, a general method for analysing the urine was detailed; a process will now be given which is adapted to any fluid that may be presented for examination:—

116. The first step is to ascertain its physical appearance. This, with the naked eye, is readily accomplished, and the result should be carefully noted.

The leading points are the colour, transparency and aspect of solid or semisolid substances, which are either suspended in it or constitute a deposit. The colour of animal fluids is usually either whitish, yellowish, red, reddish or greenish-brown. The whitish colour generally depends upon the presence of minute colourless, or nearly so, particles, such as the globules of milk, the molecules of the chyle, or the minute granules of chronic abscess. The yellowish colour either arises from fatty matter, a very small quantity of the colouring matter of the blood or of the bile. The red colour depends either upon the blood or vegetable colouring matters. The former is distinguished as described in Part I. p. 36; the latter in Part I. p. 41. The reddish or greenish-brown generally arises from the colouring matter of the bile mixed with that of the blood; sometimes from the former alone. The detection of the biliary colouring matter is described at pp. 88 and 112. Examination of the solid parts with the microscope completes this part of the process. They are either amorphous, crystalline, or otherwise structural. The amorphous are composed of distinct and united particles; the former consist of either the organic granules which pervade all animal fluids, the lithates of ammonia or soda (Part I. p. 30), the molecular base of the chyle (p. 98), a finely-divided proteine substance (p. 91), and carbonate or phosphate of lime (Part I. pp. 34, 47). Of these amorphous sediments the second and third are the smallest, although they all are exceedingly minute; the organic granules are diffused, of various sizes and somewhat translucent;

and the lithates are usually coloured. The united granules are found in precipitated proteine compounds, disaggregated pus-globules and mucus; in the latter they are closely and evenly crowded; in the disaggregated pus-globules they are combined into small compound globules. But the microscopic appearance of these substances is not characteristic. The crystalline substances are readily distinguished by their peculiar forms; all such as are found in animal fluids are figured in the four Plates. Those most commonly occurring are the ammonio-magnesian phosphate, cholesterine, uric acid and oxalate of lime; they are readily recognised with the microscope. The spherical globules are generally composed of fatty matter. The third kind is generally composed of minute cells, which are spherical and granular on the surface in those from pus, mucus, chyle and lymph; they yield nuclei when treated with acetic acid, especially those from lymph and pus, and the differences between them are very slight and inconstant. When from the blood, they are characterized as at p. 64; when composed of epithelium, they are large, oblong and irregular, the surfaces being more finely granular; they also contain a single large nucleus, which with the cell-wall is insoluble in acetic acid. In some fluids we find fibres of fibrine or mucus, infusoria and ferment-plants.

117. The next point is the separation of the solid from the fluid parts. This may be frequently accomplished by placing the fluid aside in a tall glass vessel, and at the end of some hours decanting the upper portions. Filtration is the most perfect method,

when it can be effected; in many it cannot. If this be the case, dilution of the fluid with water will sometimes enable us to succeed; at others, the admixture of saline solutions, as those of sulphate of soda or chloride of sodium (p. 91). It is best to filter first through linen or coarse paper, subsequently using finer.

118. When the clear fluid is separated, its acidity or alkalinity should be noticed. This is readily effected (p. 1). The amount of free acid may be ascertained by carefully neutralizing a weighed portion of the fluid with a dilute solution of ammonia or carbonate of soda, the exact strength of which is previously known. It may be added from a graduated tube, agitating the mixture each time until it is just commencing to react as an alkali upon the test-paper. Thus the quantity of the solution used and its strength being known, the amount of the acid saturated is easily found. The amount of alkali is ascertained in exactly the same manner, substituting a dilute acid of known strength for the alkaline solution. The acid reaction is generally derived from either acetic, lactic or butyric acids, or from acid salts, as superphosphates. The alkaline reaction generally arises from either carbonate of soda or carbonate of ammonia. The method of recognizing these acids and bases have been described in their respective places.

119. The next stage is the qualitative analysis of the fluid. The ordinary substances which occur are the following:—

1. Proteine compounds { Caseine. Fibrine. Albumen, globuline Oxides of proteine.
2. Fatty matters { Acid:—Oleic, margaric, stearic. Neutral:—Oleine, margarine, stearine, butyrine, cholesterine and glycerine.
3. Sugar:—Lactic, diabetic.
4. Bilic acid, or the products of its decomposition.
5. Urea, allantoin.
6. Colouring matters:—Hæmatine, cholepyrrhine.
7. Acids { Organic:—Acetic, lactic, butyric, hippuric, uric, benzoic. Inorganic:—Sulphuric, phosphoric, muriatic.
8. Bases { Volatile:—Ammonia. Fixed:—Soda, potash, lime, magnesia, oxide of iron.

120. If any semisolid matter is present as a deposit, if it is firm and rendered more transparent by acetic acid, it is fibrine; if it is rather coagulated by the acid, rendered softer, and exhibits under the microscope mucus-corpuscles and epithelial scales, it is mucus.

121. A small quantity of the fluid is next heated to the boiling-point. If it is now found acid, and no precipitate falls, no albumen is probably present; if it is acid, and a precipitate does fall, albumen is present. If it is neutral or slightly alkaline, a very small quantity of a dilute acid should be added, so as to neutralize it exactly; if no precipitate falls, no albumen is present. If a precipitate has formed, it should be allowed to subside; if it is red or reddish-brown, and the liquid is almost decolorized, albumine and hæmatine are present.

122. Acetic acid is then added, either to another portion of the fluid, or to that poured off from the deposit; if a precipitate fall, caseine is probably

present. This suspicion is confirmed by the precipitate being soluble in excess of the acid, and its being amorphous. If it is not soluble in acetic acid, that modification of tritoxide of proteine called pyine is present.

123. If, after the ebullition of the fluid and separation of the albumen, alcohol cause a precipitate, one of the oxides of proteine is present; if the precipitate be soluble in the dilute mineral and acetic acids, and the solution be precipitated by ferrocyanide of potassium, it is the binoxide; if not, the tritoxide.

124. If allantoin, uric or hippuric acids be suspected to exist in the fluid, a portion should be boiled, filtered and evaporated to one-fourth; if allantoin be present, it crystallizes (Plate IV. fig. 28). It is soluble with difficulty in cold water, and also in alcohol. Another portion is treated with a drop or two of muriatic acid, and gently evaporated. If long prisms separate, hippuric acid is probably present; if minute rhombs subside, lithic acid is present. If the crystals are thin and very insoluble in water, they are probably composed of benzoic acid. Each precipitate must be tested as regards the reactions for these acids (Part I. p. 21 and 44, and Part II. 41).

125. If, on the addition of nitric or muriatic acid to the fluid, a green precipitate falls, or the fluid acquires a green tinge, or passes through the series of tints (p. 112), the colouring matter of the bile is present.

126. Bilic acid, or the proper biliary matter, may be detected as at p. 88.

127. After evaporating a portion of the fluid to

dryness and exhausting it with æther, the residue of the evaporation of the æther may be tested as at pp. 22 and 35, to separate the fatty matters.

128. Urea may be detected as at p. 89. Sugar is detected either by Trommer's test or fermentation, and the presence of the *torulæ*.

129. The inorganic constituents may be best detected as at Part I. p. 24, and estimated as in the analysis of the serum of the blood (p. 83).

APPENDIX.

1. It has been recently found that Becquerel's table for ascertaining the amount of solids in urine gives too low an estimate. Dr. Christison has proposed a more accurate proportion, which is found by multiplying the difference between the specific gravity of the urine and 1000 by 2·33; the result gives the amount of solids in 1000 grs. Inasmuch as these tables are only intended to afford a ready means of roughly estimating the amount of solids passed *per diem*, they sufficiently answer the purpose; but the experimenter will frequently find, on testing them by evaporating the urine to dryness, and thus directly estimating the solid residue, that his results will at one time agree with one table, at another with a different one; this arises from the facility with which some of the constituents of the urine are decomposed, especially the urea.

2. Scherer has recently examined the extractives and colouring matter of the urine. He considers that what has hitherto been considered the extractive of the urine is a peculiar substance, which is analogous to the animal colouring matters. He finds that its elementary composition varies. It may be precipitated by various chemical substances, especially acids and both acetates of lead; but its composition

varies in the urine of different individuals. He found its composition thus:—C 58·43, H 5·16, N 8·83, O 27·58. It was obtained by first treating the urine with nitrate of baryta, and then with the neutral and basic acetates of lead. The precipitate was washed, warmed with muriatic acid and alcohol, filtered when cold, then evaporated and washed with water. When dissolved in water with a little potash, and then treated with nitric acid, it yields the alterations in colour which are characteristic of the biliary colouring matter.

3. The composition of urea per cent. is as follows:—C 20·02, H 6·71, N 46·73, O 26·54. An excellent process for estimating the quantity of urea is this:—A weighed quantity of urine (90–100 grs.) is treated with basic acetate of lead until it ceases to yield any further precipitate; the mixture is set aside, filtered, and sulphuretted hydrogen passed through the solution to separate any excess of lead; the fluid is evaporated, mixed with sulphuric acid in the proportion of about half the weight of the urine used; the mixture is then heated over a spirit-lamp or sand-bath at a heat of about 380° until the evolution of carbonic acid commences, the vessel is then covered and the heat continued until the evolution of carbonic acid ceases, the temperature being kept below 572°. The carbonaceous residue is then mixed with water, the solution filtered, and evaporated until almost all the water has passed off. A small quantity of muriatic acid is then added to the residue, and a sufficient quantity of chloride of platinum mixed with alcohol and æther, to render the solution of a yel-

low colour. The whole is set aside, the precipitate separated by filtration, washed with alcohol and a little æther, dried and heated to redness; the residue is then treated with boiling dilute muriatic acid, the solution filtered, the pure platinum then dried and heated to redness. This amount of platinum corresponds to the ammonio-chloride of platinum formed from the ammonia salts present in the urine, with that formed from the decomposition of the urea; and the potassio-chloride of platinum formed from the decomposition of the potash salts in the urine. The amount of platinum corresponding to the ammonia and potash salts existing in another portion of the same urine must be estimated by a separate experiment and deducted from the above total quantity; it is variable. M. Heintz found it between 0·1 and 1·16 per cent. The same chemist found that the extractives of the urine yielded as much ammonia as would correspond to 0·018 per cent. of urea; this quantity is however so small, that it may be overlooked. 100 parts of ammonio-chloride of platinum are equal to 13·4498 of urea; also, 100 parts of pure platinum are equal to 30·401 of urea.

4. The occurrence of lactic acid in the urine has been carefully examined by numerous observers; they agree in the conclusion that it does not happen. A peculiar substance has been shown to exist in this fluid, which in some of its properties resembles lactic acid; especially in forming a crystalline compound with oxide of zinc, which assumes the form of four-sided prisms; these are however terminated by oblique terminal surfaces, and the substance contains

a large quantity of nitrogen. It is most probable that this compound has been mistaken for the lactate of zinc.

5. Liebig has shown that hippuric acid is a constant ingredient in urine. It is best separated by evaporating the fluid until most of the salts are deposited, adding strong alcohol and applying heat. The clear solution is then to be poured off, evaporated nearly to dryness, the residue redissolved in hot water, the urea decomposed by passing a current of chlorine through the solution, a small quantity of muriatic acid added, and the mixture concentrated by gentle evaporation. The hippuric acid then crystallizes.

6. The composition of cystic oxide per cent. is—C 30·01, H 5·10, N 11·60, O 28·38, S 25·51.

7. The composition of diabetic sugar per cent. is—C 40·156, H 6·705, O 53·139.

8. Of xanthic oxide,—C 39·28, H 2·95, N 36·35, O 21·42.

9. Of uric acid,—C 36·083, H 2·441, N 33·361, O 28·126.

10. Simon has pointed out the existence of some curious minute bodies in the urine under certain circumstances. They form cylindrical sacs, having distinct walls, and are of such a diameter as to permit mucus-corpuscles to move freely within them, and are either completely or partially filled with a granular matter; also elongated masses, having the form of these cylinders, but without any distinct parietes, and evidently the contents of the cylinders. They are probably composed of a fibrinous exudation

from the walls of the urinary tubules. They are well seen with a power of 300, or even less, and are found in cases where the urine is albuminous, or in cases of irritation of the kidneys, in which this occurs at a subsequent period.

11. By filtering the saliva and treating it with 5–6 times its weight of absolute alcohol, M. Mialhe has obtained a remarkable substance, which closely resembles diastase, and which he believes to be identical with it. It exerts exactly the same action upon starch as vegetable diastase. It is precipitated by the alcohol, and should be collected on a filter, and whilst still moist should be placed upon a plate of glass, and dried in a current of air at 104°–122° F. Nothing is known of its composition. Is it an oxide of proteine?

12. The amount of sulphocyanic acid in the saliva is best estimated by evaporating a weighed portion of the saliva to dryness, exhausting the residue with alcohol, evaporating the alcoholic solution, dissolving the remainder in water, raising the solution to the boiling-point, and then adding a mixture of chlorate of potash and muriatic acid. The sulphur is thus oxidized, and the sulphuric acid formed is precipitated by a soluble salt of baryta. 100 parts of sulphate of baryta correspond to 25·11 of sulphocyanogen, or 41·91 sulphocyanide of potassium*.

13. In preserving microscopic objects, perhaps the best substance for cementing the thin glass to the slide is black Japan varnish; although, provided the walls of the cell be made on the slide, and allowed

* Pettenkofer.

to dry thoroughly before the thin glass is applied, the kind of cement is not of great consequence.

14. The mode of drying substances in a water-bath is well known. The substance, placed in a crucible, should be kept in the bath until the total weight ceases to diminish.

15. It is also perhaps unnecessary to state, that previous to pouring a liquid upon a filter, the filter should be moistened with either water, alcohol or æther, according to the nature of the fluid to be separated from the precipitate. In washing precipitates, the process should be continued until a drop of the liquid from the beak of the funnel leaves no or an inappreciable amount of residue on evaporation.

16. A few filters, which have been perfectly dried at 212°, should be kept, so as to be at hand when precipitates which must be dried at 212° are required; after the drying of the filter and the precipitate together, by deducting the weight of the former from the total weight, that of the precipitate is left.

DESCRIPTION OF THE PLATES.

PLATE III.

Fig. 1. Margarine from human fat. *a* and *b*, minute branched needles; *c*, tufts composed of needles more rapidly formed; *d*, drops of oleine. 150 diameters.

2. Stearine. It is rarely found to exhibit any distinctly crystalline form; that figured however sometimes occurs.

3. Also margarine, more highly magnified. *a*, tufts composed of ramified needles; *b*, the same, more highly magnified.

4. Sebacic acid. *a*, prismatic form; *b*, thin plates; *c*, minute tufts; *d*, the same, more highly magnified. These forms are found in the acid crystallized for the first time from a hot aqueous solution of the products of distillation of a fat containing oleine; *e*, the same, recrystallized and pure, exceedingly thin elongated laminæ.

5. Margaric acid. 150 diameters. These crystals somewhat resemble those of margarine.

6. Stearic acid. 150 diameters.

7. Oleine.

8. Cholesterine. Thin rhomboidal plates, the angles occasionally truncated.

9. Muriate of ammonia. The form *a* approaches very near the dagger-shaped crystal of chloride of sodium and urea.

10. Lactate of zinc.

11. Acetate of zinc. These are very thin plates.

12. Carbonate of lime. See p. 58, note.

13. Ammonio-phosphate of soda from urine by evaporation. After Simon.

PLATE IV.

Fig. 14. Blood. *a* and *b*, coloured corpuscles: *a*, as ordinarily seen; *b*, lateral view, when turning over; *c*, colourless corpuscles; *d*, after treatment with acetic acid, exhibiting nuclei.

15. Blood during coagulation; the coloured corpuscles forming areolar spaces by the adhesion of their plane surfaces, the colourless corpuscles remaining distinct.

16. Blood before coagulation commences. Seen with a much lower power than in 14.

17. Oxalate of soda. *a*, dumb-bell form; *b*, prisms; *c*, tufts.

18. Epithelial scales and mucous corpuscles.

19. Mucus (nasal). *a*, epithelium; *b*, mucous corpuscles; *c*, granular matter; *d*, fibrous appearance. Less highly magnified than in the last figure.

20. Nitrate of urea, crystallized from blood in Bright's disease.

21. Nitrate of soda, from an aqueous solution of the alcoholic extract of blood.

22. Tartrate of lime.

23. Milk-sugar. *a*. tufts (after Vogel); *b*, prisms.

24. Benzoic acid. *a*, by sublimation; *b*, by crystallization. From cow's urine.

25. Corpuscles of pus. *a*, ordinary; *b*, after the addition of acetic acid.

26. Fatty globules from the colostrum, somewhat resembling the globular masses in sour milk.

27. Bitartrate of potash.

28. Allantoin.

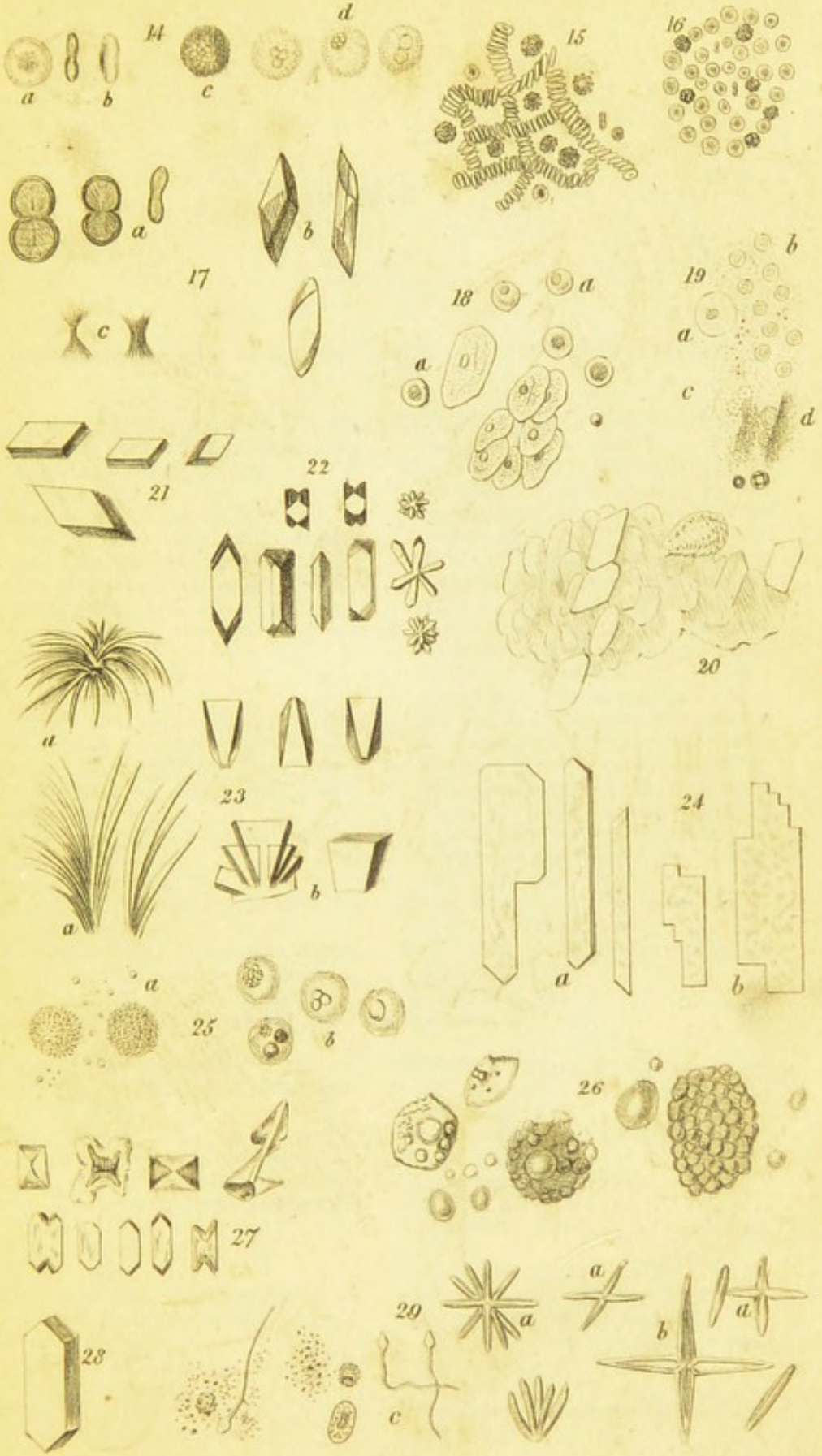
29. Semen, containing crystals of phosphate of lime.

Plate III.

J.W. Griffith. ad nat. del.

J.D.C. Sowerby. sc

Plate IV.



J.W.Griffith ad nat. del.ª

J.D.C.Sowerby sc.ª

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*** The figures to which the Roman character is affixed refer to Part I.

THE END.

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