RESEARCHES

ON THE

CHEMISTRY OF FOOD

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EDITED FROM THE MANUSCRIPT OF THE AUTHOR,

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EDITOR'S PREFACE.

IN *offering to the British public the present* translation of the latest work of Baron Liebig, I may be permitted to say, that I feel highly honoured in being intrusted with the duty of conveying to my countrymen a knowledge of one of the most interesting and valuable investigations which has yet been made in Animal Chemistry.

The researches into the nature of the soluble constituents of muscle or flesh, which constitute the chief part of the present work, are preceded by considerations on the true Method of Research in Animal Chemistry, which are worthy of the most earnest attention on the part of those who intend to devote themselves to investigations in this most important and at the same time most difficult department of science. A careful study of this section will convince the reader that much more might have been done of late years in Physiological Chemistry, but for the wrong direction unfortunately given to recent researches, and will powerfully contribute to direct into the right channel the energies of those rising chemists to whom Britain must look to sustain her scientific reputation in the present age of rapidly advancing discovery in the most recondite parts of Organic Chemistry and of Physiology.

The physiologist will also find in this introductory section, the most convincing reasons to show that, henceforth, it is indispensable that Anatomy, structural Physiology, and Chemistry should unite their forces with a view to the solution of the great questions which it is the common object of these sciences to solve.

With regard to the chemical researches contained in the present work, it is most emphatically to be stated, that they constitute only the first steps in an almost new career; that they are very far from exhausting even the single subject here investigated, namely, the nature of the soluble constituents of the muscles; and that, consequently, they are chiefly valuable as indicating the true path at present to be pursued by chemists. It would be contrary to the principles as well as to the wishes of their author, if physiologists were to regard them as completed, or as in any one point exhausting the subject; and how many more subjects does the animal organism present, which must remain obscure and impenetrable till they shall be studied on principles analogous to those which have guided the author?

Nevertheless, these researches have already thrown much light on many important but obscure *questions; and independently of the interest which,* in a purely chemical view, they must always have for the chemist, they will be found, by the physiologist and the medical man, both interesting and valuable in a very high degree.

In connection with previous researches, they serve to demonstrate, that the more we know of the processes going on in the organism, the more do we find these to involve strictly chemical changes, and to be capable of a chemical interpretation. It would indeed appear as if every change in the organism were attended by a definite chemical or physical action; and although we shall probably never succeed in unveiling the nature of the peculiar influence, called vitality, under which these changes occur, yet the present as well as previous investigations render it certain that we have still a great deal more to discover concerning the share taken by chemical action in the vital processes.

I *cannot omit to direct the attention of physio-* logists to the proofs, contained in the following pages, of the truth of the principle, that every property, however apparently trifling or minute, possessed by any constituent of the organism, even by such as occur only in very small proportion, has its destined use and function; and, consequently that every constant difference, whether of composition, of form, or of quality, in the different tissues and fluids, must likewise correspond to a difference of function, in which, as a general rule, it cannot be replaced, nor its absence compensated for, by any other substance, however analogous in most of its properties.

A striking example of this truth will be found in the *facts concerning the great preponderance of* phosphate of potash and chloride of potassium in the juice of flesh, while in the blood and lymph which circulate through the muscles, it is phosphate of soda and chloride of sodium which prevail. Another will be found in the fact that the juice of flesh is always strongly acid, while the blood and lymph are decidedly alkaline; and a third is seen *in the abundant supply of* lactic acid *in the juice of* flesh, while it cannot be detected in the urine.

But perhaps the most interesting observation, next to the discovery of kreatine as a constant ingredient of flesh, of kreatinine, a powerful base, in the juice of flesh, and of both in urine, is the demonstration, complete, as it appears to me, of the true function of the phosphate of soda in the blood.

This function, that of absorbing carbonic acid and giving it out in the lungs, is here shown to depend entirely on the minute chemical characters of the salt in question; and we now see how it happens that phosphate of soda is essential to the blood, and cannot be replaced by phosphate of potash, a salt, which, although in many points analogous, differs entirely from phosphate of soda, in its tendency to acquire an acid instead of an alkaline reaction, and in its relation to carbonic acid. In this way, the beautiful researches of Graham on the phosphates are now finding their application, in the minutest point, to physiology. The same remark applies to the action of common salt on phosphate of potash, which satisfactorily accounts for the presence of phosphate of soda in the blood of animals whose food contains only phosphate of potash, but which either find common salt in their food, or obtain it as an addition. Surely such facts as these must convince all men of the value of the most minute study of the chemical properties of all the substances which occur in the organism, however these properties may at first appear trifling or unimportant; and of the utter impossibility of making progress in Physiology without the aid of Chemistry. I would also direct attention to the evidence here given of the fact, that the parietes of the different systems of vessels, as well as the membranes and cells, must possess, in the living body, a power of selection, or, in other words, different degrees of permeability, in reference to the various substances which penetrate them by endosmose. To this subject the investigations of the Author *have been more particularly directed, since the* termination of the present work; and results of great interest and value have been already obtained.

The medical man will find in these Researches a prospect of many and great improvements in practice, whether as regards dietetics, or the action of acids, alkalies, and salts on the digestive and respiratory processes; and with respect to both, it is to Chemistry that he must look for assistance in his efforts to advance. Lastly, the present work contains some most valuable practical applications of the chemical discoveries therein detailed, to an art which immediately concerns the whole of mankind; namely, the culinary art.

The subjects of the preparation of meat for food by boiling, roasting, and stewing; the true nature and proper mode of preparation of soup, as well as of the extract of flesh or genuine portable soup; and, finally, the changes produced in meat, not only by the above processes, but by salting, and the conditions necessary in each case to insure the digestibility and nutritive qualities of the flesh or soup, are here, for the first time, investigated on scientific principles; and in all these points, Chemistry is found to be the means of throwing light on that which was obscure, and of improving our practice by the application of rational principles.

In conclusion I would remark, that the apparent simplicity of the results, and even of the processes described, gives a very inadequate idea of the laborious and difficult nature of the investigation. Having myself repeated several of these processes, I have been enabled to perceive, that, unless Baron Liebig had devoted to the subject his whole energies for a long time, and unless, moreover, he had operated on a scale so large as few experimenters would have ventured on, the whole subject would have remained as obscure as ever. Not the least valuable lesson to be derived from this work is the absolute necessity of experimenting on a very large scale, if we would obtain satisfactory or trustworthy results.

WILLIAM GREGORY.

UNIVERSITY OF EDINBURGH,
31*st May*, 1847.

AUTHOR'S PREFACE.

THE preparation of a new edition of my Animal Chemistry rendered it desirable, and even necessary, to subject to an experimental inquiry and criticism the chemical observations made, up to that period, in this department of the science. I was thus induced to engage in a series of researches, which have led me farther than I at first anticipated. The questions as to the nature of the organic acid diffused through the muscular system, and that of the other substances contained in that system, appeared to me so important for the right understanding and explanation of the vital processes, that I did not feel justified in proceeding with the revisal of my work until these questions had been, at least to a certain extent, experimentally answered.

The present little work contains the analytical details of my investigation on these subjects, which, in accordance with the plan of the Animal Chemistry, could not be introduced into that work.

As my experiments include the changes which flesh undergoes in its preparation for food, I trust that not only physiologists and chemists, but also the lovers of a rational system of diet, will find in the following pages many observations worthy of their attention.

DR. JUSTUS LIEBIG.

GIESSEN, 1*st June,* 1847.

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RESEARCHES

ON THE

CHEMISTRY OF FOOD.

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On the Methods of Investigation in Animal Chemistry.

Chemists have not devoted their energies to Animal Chemistry and Physiology.

If we consider with some attention the facts which have been ascertained in Animal Chemistry, we shall be surprised to find how few among them there are, on which conclusions can be securely based. The cause of this appears to me to be, that hitherto but a very small number, comparatively, of professional chemists have occupied themselves with the cultivation of this department of the science, or have selected it as the object of profound and thorough investigation. The important researches which Berzelius began forty years ago, as well as those of L. Gmelin, Braconnot, and Chevreul, have not been imitated or followed up in the same spirit which animated these men. No chemist has yet appeared who has chosen, in Animal Physiology, as De Saussure did in Vegetable Physiology, the first and most important questions as the problem of his life. Hence it comes, that in Animal Chemistry, which is a frontier district, belonging entirely neither to Chemistry nor to Physiology, as commonly happens on the frontiers of thinly-peopled countries, *adventurers of all kinds roam about; and it is on* the observations made, and the tales related by these adventurers, during their occasional expeditions or excursions, that the greater part of our knowledge of this district rests. But how few of them have attained so accurate a knowledge, even of the small tract over which they have passed, that those who follow them run no risk of losing their way! It is one thing to travel through a country, and another, very different, to establish a home therein.

Animal Chemistry has been in the hands of adventurers.

Consequences of this.

Since none of those philosophers who are called to possess this country, and who should draw from its fertile soil useful fruits, in the form of prolific points of view, and imperishable truths, takes the trouble to follow the devious path of these adventurers, and to test the accuracy of their statements, they are induced, either to reject all these tales as vague and unfounded, or to regard them as actual truths. If one experimenter, for example, has found, in this or in that quarter, nothing which seemed worthy of his attention, they conclude that there is nothing whatever to be found there; and if another proclaims the rich treasures of a different district, they act as if they were already in possession of these; they build bridges over rivers, and drive mills with their waterfalls; but these are bridges over which no one passes, and mills that yield us no flour.

Exploded errors in medical theory.

For centuries past, men have endeavoured to discover methods of cure, or a knowledge of morbid conditions, by the aid of the imagination, in the so-called systems of medicine; as if it were possible, or even wise and judicious, to expect a true insight into these things, or to look for intellectual illumination and progress from the most hazardous of all games of chance.

The chemist has no direct interest in Physiology and Pathology.

In modern times this method has been abandoned as entirely unproductive; but, on the other hand, men commit an error not less grave, inasmuch as, instead of acquiring by their own researches the knowledge necessary for the solution of their difficulties, they leave this duty to others, who, fully occupied with the cultivation of their own branch of science, have neither interest in the questions to be solved, nor inclination for the task. From the chemical analysis of blood, of urine, or of a morbid product, they expect an aid which these analyses can never afford, as long as the results of the chemist are not brought into the true connection with the conditions which they are to explain, or with the causes which have produced these conditions.

Pathologists neglect pure chemistry.

All the new facts daily ascertained by the chemist are regarded by pathologists as being exactly those which are of no direct use to them, because they have no clear idea of that which they require; because they are unable to connect with these chemical discoveries any question to be solved, or to draw from them any conclusion.

Erroneous views in regard to the nature of the connection between medicine and chemistry.

What an inconceivable delusion, what a confusion of ideas must exist, when a physician thinks, that from the complex results of an analysis of the blood, he can draw a conclusion as to the nature and the cause of a disease, and can found on this a method of treatment, when we have not yet advanced so far in physiology as to bring into relation with the digestive process one of the simplest chemical facts, namely, the absence of alkaline phosphates in the urine of the herbivora! What pathologist has ever yet attempted to fix and define the notion of bad or spoiled food, in its full signification, by means of a logical comparison with good and wholesome food? and yet the former are regarded as the proximate causes of diseased conditions. I readily admit, that for such an investigation chemical knowledge is indispensable; but the investigation itself has no value in reference to chemistry, and constitutes no object of research for the chemist, as such.

Want of mutual connection between chemistry and physiology,

From this state of things, which depends on the want of connection between the labours of chemists and those of physiologists, it has happened, that Animal Chemistry, during the last ten years, has gained little more than a more accurate knowledge of those compounds which the animal organism applies to no further purpose in its economy; and that, at the present time, it seems as if all the wonderful properties which it exhibits were produced only by means of albumen, fibrine, gelatine, some cerebral or nervous matter, and a little bile. It is universally felt, that we are as far from a true animal chemistry as the anatomy of the last century was from the physiology of the present day. Indeed the animal chemistry of our time cannot be compared to modern anatomy, since microscopic researches have established the existence of structures which had entirely escaped the earlier investigators; of structures, as is now known, on which alone the function of those formerly observed depends.

has greatly retarded animal chemistry.

We know that the aliments of all plants are precisely the same; but what a multitude of forms do these assume in the organisms of different plants! The same soil on which we grow grain, beet-root, or potatoes, yields also tobacco and poppies. In grain and potatoes we have starch, in beet-root, sugar, in all three, a certain amount of compounds containing sulphur and nitrogen; in the poppy, a fat oil and a series of organic bases,—containing nitrogen, but not sulphur,—which are not found in other families of plants; in tobacco, a volatile oil,—containing nitrogen,—possessed of basic or alkaline properties.

Varied results of vegetation

These substances, so different in composition, are all derived from the same compounds, which nature supplies as food to all plants. It is certain that the differences in the nature and composition of these products can only be determined by variations in the organisation of the plants which produce them; for they are the visible signs of existing peculiar agencies, and chemistry, which has succeeded in detecting so great a variety in these compounds, belonging only to certain vegetable families, has thus, in her department, surpassed vegetable anatomy. But the case is entirely reversed, when we compare the progress of animal anatomy with that of animal chemistry. The chemical relations which must correspond to the different structures and tissues are altogether unexamined; and yet we cannot suppose otherwise than that the nature of each secretion must stand in a definite relation of dependence, in reference to its composition and its chemical properties, with those of the substance from which it is formed, or with those of the parts which are concerned in its formation.

must depend on differences of organisation in plants.

The varied secretions of the animal body

If we suppose, that it is from the blood that all the constituents of the animal body are formed, this can only take place in virtue of certain forces, which belong, not to the blood, but to the organs in which the component parts of the blood are employed to produce them. The direction and position, the peculiar arrangement of the elements of the constituents of the blood in the process of nutrition, are changed according to these seats of peculiar direction in the force acting in the body, which have the same relation to the blood as the different vegetable

must depend on similar causes; not yet studied.

families have to the analogous substances which they receive as food from the air and the soil.

Agency of decomposing animal compounds.

There is, probably, no fact more firmly established, as to its chemical signification, than this, that the chief constituents of the animal body, albumen, fibrine, the gelatinous tissues, and caseous matter, when their elements are in a state of motion, that is, of separation, exert on all substances which serve as food for men and animals, a defined action, the visible sign of which is a chemical alteration of the substance brought in contact with them.

Transformations depending on the presence of ferments.

That the elements of sugar, of sugar of milk, of starch, &c., in contact with the sulphurised and nitrogenised constituents of the body, or with the analogous compounds which occur in plants, when these are in a state of decomposition, are subjected to a new arrangement, and that new products are formed from them, most of which cannot be produced by chemical affinities, this is a fact, independent of all theory. Chemical affinities exert an influence on the nature of the new products, but do not determine their formation. The cause of this is obvious. When an organic substance is decomposed by a chemically active body, we can, in most cases, predict the nature and the properties of the new products formed by its action. If the active chemical agent be an acid, all, or a part of, the elements of the organic body combine to form a base, or to form water; if it be a base, they unite to form an acid, that is, a compound, the properties of which

Agency of ferments compared with that of ordinary affinity.

are opposed to those of the acting body, and by which, therefore, its affinity is neutralised. In the processes called fermentation and putrefaction, the mode of arrangement of the elements of organic compounds is of a totally different kind; because here it is not a foreign chemical attraction, but another cause, which determines the new arrangement. Now we know, with absolute certainty, that the products which may be generated from fermentescible substances vary, as the state of the ferment or exciter varies. The same caseine, the same membrane, which determine the transposition of the elements of sugar so as to form lactic acid, cause, in another state, the same elements to divide themselves into carbonic acid and alcohol, or into butyric acid, carbonic acid, and hydrogen gas.

The transformation caused by a ferment varies with the state of the ferment.

These principles are concerned in the vital processes.

No one can fail to perceive the significance of these facts, in respect to the understanding and the explanation of many of the vital processes. If a change in the position and arrangement of the elementary molecules of animal compounds can exert, out of the body, a decided influence on a number of organic substances, when brought in contact with them; if these substances are thus decomposed, and new compounds formed of their elements; and if we consider, that among these compounds, namely, such as are susceptible of fermentation, are included all those matters which constitute the food of man and of animals, it cannot be doubted, that the same cause plays a most important part in the vital process; that it has a great share in the alterations which nutritious matters suffer when they are converted into fat, into blood, or into the constituents of organised tissues. We know, indeed, that in all parts of the living animal body a change takes place; that portions of living tissues are separated; that their constituents, Fibrine, Albumen, Gelatine, or whatever they may be called, give rise to new compounds; that their elements combine to form new products; and in the present state of our knowledge we must suppose that, by means of this very action, at all points where it occurs, according to its direction and force, a parallel, or corresponding, change is effected in the nature and composition of all the constituents of the blood or of the food which come into contact with them; and that, consequently, the change of matter is itself a chief cause of the transformations which the constituents of the food undergo, and also a condition of the process of nutrition. We must further admit, that with every modification produced by a cause of disease in the process of transformation of an organ, of a gland, or of one of their constituents, the action of this organ on the blood conveyed to it, or on the nature of the resulting secretion, must, in like manner, be changed; that the effect of a number of remedies depends on the share which they take in the change of matter; and that such remedies exert an influence on the quality of the blood or of the food, chiefly in this way, that they alter the direc-

The change of matter is a chief cause of the transformations of the food.

The change of matter is influenced by diseases and by remedies.

tion and force of the action taking place in the organ, which action they may accelerate, retard, or arrest.

Relation of urea, uric acid, &c. to the food, very little known.

The intermediate members of the almost infinite series of compounds which must connect Urea and Uric acid with the constituents of the food, are, with the exception of a few products derived from the bile, almost entirely unknown to us; and yet each individual member of this series, considered by itself, inasmuch as it subserves certain vital purposes, must be of the utmost importance in regard to the explanation of the vital processes, or of the action of remedies. The chief constituent of bile is a crystallisable compound; and no physiologist now denies, that it is indispensable for the process of digestion.

The arrangements found in the body must have reference to the vital processes.

Were we to discover in the organism certain arrangements by which a permanent electrical current must be determined at all points, could any one doubt that such a current must take a share in the vital processes? Or if it were proved, that from the constituents of the food of all animals, among other compounds, organic bases are formed, which in their chemical nature resemble caffeine or quinine, or any other organic base; if such compounds could be detected everywhere, in all parts, or only in certain parts, of the organism, should we not have advanced a step nearer to the explanation of the action of caffeine or of quinine?

About ten years since, the ultimate analysis of organic bodies furnished physiology with a result

Erroneous deductions from the supposed identity in composition of fibrine, albumen, and caseine.

highly important, in order to the easy understanding of the digestive or nutritive process, by demonstrating, that fibrine, albumen, and caseine have the same composition. Misled by this result, many chemists thought that the chief problem to be solved by chemistry was to ascertain, by ultimate analysis, the composition, in 100 parts, of all the constituents of the body; and thus many were induced to act on each of these constituents, without a more minute study of its chemical relations and its properties, with alcohol, ether, and acids; and with the aid of the known resources of organic analysis, to determine the percentage of carbon, nitrogen, hydrogen, and oxygen. They believed that they had thus, by means of these numerical results, done a real service to physiology, although the only addition thus made to the name of the substance analysed was an empty formula, of the accuracy of which there was no evidence whatever. Now that we have been for ten years in possession of these formulæ, every one must perceive that we have made no real progress. The cause of this is obvious to all who know the true value of ultimate analysis. Ultimate analysis is a means of acquiring knowledge, but is not itself that knowledge. Even supposing, what no one will seriously maintain with regard to the constituents of the animal body, that analysis had made us acquainted with the exact proportions in which their elements are united together, yet this knowledge gives us not the least in-

No progress has been made by the aid of mere formulæ.

The mode of arrangement of the elements is the essential point.

formation as to the arrangement of these elements, or the way in which they group themselves, under the influence of chemical agencies. Now it is the knowledge of both these things together which alone can lead us to definite views as to the part which these compounds play in the vital processes, or the changes to which they are subjected up to the period of their expulsion from the body; and this is essentially the problem which Chemistry has to solve in reference to the vital process.

Ultimate analysis is not sufficient.

Ultimate analysis, by itself, has this peculiarity, that in the case of very complex substances it cannot secure the chemist against errors, because there is no other control for the accuracy of the analysis than the analysis itself; and because the errors are equal at different times, and escape notice when we cannot change the methods of determining the individual elements. Now there is as yet no means of determining the weight of carbon otherwise than in the form of carbonic acid, or that of hydrogen otherwise than in the form of water.

It must be accompanied by the study of products of decomposition.

The only way to attain an accurate expression for the composition of those substances, which, like the constituents of the animal body, contain a very large number of elementary molecules in the complex atom of the compound, is to endeavour to resolve it into two or more less complex compounds, and to compare the composition and the amount of these products with those of the body from which they have been derived.

In this respect, the history of Salicine offers the most striking instance, and may serve to convince every one how little can be attained in questions of this kind by means of ultimate analysis alone. Five of the most accurate and conscientious chemists endeavoured, with all the dexterity which they are known to possess, to fix the relative proportion of the elements in salicine (a body of a far less complex nature than animal substances), but without the slightest success, until a method, discovered by Piria, of resolving salicine into two other compounds, at once, and without further exertion, removed the difficulty. For each compound there is but one correct formula, but there are innumerable formulæ which approach the truth; and it can only occur by the rarest chance that a chemist succeeds in discovering the true formula of a compound from the results of its ultimate analysis. But the confidence which we repose in the dexterity of a chemist can never furnish a foundation for theoretical views; and it has not yet been the lot of any analyst to stand free from error in this respect. Those chemists who have enriched the science with the greatest number of true formulæ, have only attained this success by means of their own erroneous formulæ.

Example from the history of Salicine.

The method just pointed out for attaining an accurate formula has not, however, escaped the notice of those who regard ultimate analysis as the last and highest object of a chemical investigation; but

Erroneous application of this method.

the utterly fallacious application of this method has misled them into far greater errors and inaccuracies.

Fallacious equations.

They believed, for example, in studying a substance, that they had fulfilled all the requisite conditions when they had succeeded in representing its decomposition in the form of an equation, without caring whether the formulæ which made up the equation represented actual substances, or existed merely in their imagination.

The following example will serve to place in a clear light what is here intended.

Illustration from the action of nitric acid on uric acid.

When we dissolve uric acid in diluted nitric acid, carbonic acid and nitrogen gases are given off in equal volumes, and we obtain an acid solution, which, if neutralised by baryta, leaves, on evaporation, a mass soluble in alcohol, with the exception of the nitrate of baryta. The products of the decomposition of uric acid by nitric acid, are, therefore, carbonic acid, nitrogen, and the above-mentioned residue soluble in alcohol. Now it is evident, that if we ascertain the weight of the uric acid and that of the residue, the composition of the latter, and the proportions by weight of the carbonic acid and nitrogen disengaged, the decomposition may now be expressed in a perfectly correct equation, on one side of which we have the formulæ of a certain quantity of nitric acid and water, and on the other, the formulæ of the product, soluble in alcohol, of carbonic acid, and of nitrogen. We should thus have performed a series of laborious analytical operations, but no investigation of the slightest scientific value; for every one knows that the product soluble in alcohol consists of at least five different substances, the relative quantity of which varies with the temperature and the concentration of the acid. If we had mixed the solution of this product with a salt of lead, we should have obtained one precipitate; with subacetate of lead, a second; and by subsequently adding ammonia, a third; which, after we had ascertained their composition, would have enabled us to insert in the equation, instead of the formula of the original product, two or three new formulæ. The equation would still have continued accurate, but it would have contained merely imaginary values, and not the formulæ of real substances, existing independently of the numbers.

Example from the proteine compounds.

If we compare with this example the investigation of the products which albumen, fibrine, and caseine yield, when acted on by strong alkalies, we shall immediately perceive, that the equations employed in books and treatises to represent the changes which occur, as well as the formulæ of the products assumed in these equations, have been obtained entirely by this fallacious method, and that these statements are utterly worthless for our purpose.

Mulder's equation,

Mulder, in his "Versuch einer physiologische Chemie," Part IV. p. 321, says: "When white of egg, or any other proteine compound, is boiled with potash, entire decomposition takes place. The prorepresenting the decomposition of proteine by alkalies,

ducts of this reaction are certainly not derived from the proteine alone, but still some of them must be regarded as constituents of that substance. These are:

	C.	H.	N.	O.
2 eq. Leucine	24	48	4	8
2 ,, Protide*	26	36	4	8
2 ,, Erythroprotide	26	32	4	10
4 ,, Ammonia	—	24	8	—
2 ,, Carbonic Acid	2	—	—	4
1 ,, Formic Acid	2	2	—	3
2 eq. Proteine + 9 eq. water =	80	142	20	33 "

A glance at this equation is sufficient to show, that the agreement is as complete as possible. On one side we have the elements of proteïne and of water, on the other, six products of decomposition; the sum of the elements being exactly equal on both sides; and yet a repetition of the experiment on which the equation is founded, teaches us that the whole explanation is utterly fallacious. For the chief product of this decomposition is a compound (possibly more than one compound) not precipitable by salts of lead; there is produced no formic acid, but oxalic acid, as well as valerianic and butyric acids; and in the case of fibrine, caseine, and the albumen of the serum of blood, there is formed a crystallisable body, Tyrosine (I give this name to

is quite fallacious.

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* *Erythroprotide is that product which is precipitated by neutral acetate of lead; protide that which is thrown down by subacetate of lead.*

the substance described by me in the "Annalen der Chemie und Pharmacie," vol. lvii. p. 127), in all, therefore, five members, which are wanting in the equation. Moreover, according to the above equation, 100 parts of white of egg should yield 30 parts of leucine, whereas, in reality, we can obtain hardly 2 per cent. of that compound.

Imperfect notions of the true province of chemical research.

Such explanations as the above are founded on an imperfect conception of the true object of a chemical investigation; and when the same author, in order to support his view, that the iron in the colouring matter of the blood exists in that compound as metallic iron (which amounts to the same thing as saying, for example, that sugar contains carbon in the form of diamond), asserts, that by leaving the red matter of the blood in contact with oil of vitriol, and then adding water, he obtained hydrogen gas; or when he states, in order to have a source, peculiar to himself, of the nitrogen in plants, that, according to his experiments, certain constituents of peat and brown coal possess the property of condensing the nitrogen of the air, and converting it into ammonia, or some similar compound of nitrogen, these statements are so many irrefragable proofs that he entertains erroneous views as to the true object of scientific researches. Without possessing the gift of prophecy, we may safely predict that we shall have, in a few years, in place of the formulæ which he has given for animal compounds, and which he regards as for ever established, entirely different formulæ.

It will fare with these analyses as with those which he has made of vegetable mucilage, of pectine, of *glycocoll (sugar of gelatine)*, and other substances, for the accuracy of which the dexterity of the chemist is for a time regarded as a guarantee, but which cease to be considered accurate, when the substances analysed become the subject of more exact investigation.

Erroneous theories impede progress.

When such fallacious principles and methods of investigation are accompanied by erroneous theoretical views, which, while they refuse admission to the most convincing evidence of the truth, are defended with a violence and obstinacy proportioned to the feebleness of these views, the field of research becomes a stage on which the most selfish passions are brought into action; but, under such circumstances, progress is out of the question.

A theoretical view is only true for the period.

A theoretical view in natural science is never absolutely true, it is only true for the period during which it prevails; it is the nearest and most exact expression of the knowledge and the observations of *that period. In proportion as our knowledge is* extended and changed, this expression of it is also extended and changed, and it ceases to be true for a later period, inasmuch as a number of newly acquired facts can no longer be included in it. But the case is very different with the so-called proteine theory, which cannot be regarded as one of the theoretical views just mentioned, since, being supported by observations both erroneous in themselves

The theory of proteine never expressed the knowledge of a given period.

and misinterpreted as to their significance, it had no foundation in itself, and was never regarded, by those intimately acquainted with its chemical groundwork, as an expression of the knowledge of a given period.

Defects of that theory.

In the "Annalen der Chemie und Pharmacie" (vol. lviii. pp. 129 et seq.), Laskowski has already fully developed the analytical evidence which bears against this theory, and we may here direct attention to the defects of the theoretical notions on which it rests, or, more properly, does not rest.

Supposed identity in composition of fibrine, albumen, and caseine

The results of the ultimate analysis of fibrine, albumen, and caseine attracted, ten years ago, the attention due to them; since they seemed to prove that these three bodies had the same composition, the notions entertained concerning the process of digestion and nutrition acquired a great degree of simplicity; these results contributed to demonstrate the value of chemical composition as an element in the discussion of physiological questions.

not necessary for the explanation of the nutritive process.

But this result, derived from ultimate analysis, had two disadvantages. The first was, that we were disposed to believe that identity of composition in the sulphurised and nitrogenised constituents of food and those of the blood was *indispensable* for the understanding and explanation of the digestive process. But, theoretically, this identity of composition is not indispensable; it only facilitated the investigation. When a chemical attraction causes the formation of a compound, it is, in regard to the chemically active, or attracting, body, quite indifferent whether the atoms which it attracts form a group, bound together by their mutual attractions, or are simply arranged near each other, without being combined. To produce the compound, it is only necessary that the attractive force should be more powerful than the forces which oppose its manifestation, that is, the formation of the new compound. *If the attractive force preponderates, the attracted* elements enter into the new combination, and this, whether they have been previously arranged in one, two, or three compound molecules or groups; and the result is exactly the same as if the attracting body had combined with one group of combined atoms.

Example. Hydrocyanic acid, for example, mixes in every proportion with water, just as many liquids do, which *may be mixed without forming a chemical combination*; but when the atoms of water and of hydrocyanic acid are in a certain degree of proximity, and we add hydrochloric acid to the mixture, the mixture acts as if it were a compound of ammonia with formic acid. The hydrochloric acid is converted into sal ammoniac, while the remaining elements unite to produce formic acid. Here the nitrogen of the hydrocyanic acid and the hydrogen of the water, two elements, belonging to two entirely distinct compounds, act, in reference to the hydrochloric acid, as if they were combined to form the compound atom which we call ammonia.

In like manner, the formation of the blood constituents would have equally admitted of explanation, and would have been equally well explained, even had the food contained, instead of *one* sulphurised and nitrogenised constituent, *two* or *three* compounds, in *one* of which was found the sulphur, in the *second* the nitrogen, and in the *third* the carbon required to make up the sum of the elements.

Fibrine differs in composition from albumen and caseine.

Under the influence of this idea of the *necessity* of identity in the chemical composition of the constituents of the blood and those of the food, Mulder was first led to assume, in fibrine, the same relative proportion of atoms of nitrogen and carbon as in albumen and caseine, in spite of the analyses of Gay Lussac and Thénard, of Michaelis, of Vogel, and of Fellenberg, all of which indicated a larger proportion of nitrogen in fibrine; and his example, or rather, the influence of his authority, reacted on several of those who followed him, who were so far misled as to reject as inaccurate the greater number of their own accurate analyses, and to give the preference to those which were defective.

Erroneous views deduced from their supposed identity.

The second, and far more serious disadvantage, was the erroneous view of the chemical constitution of the three animal substances just named, which chemists believed themselves justified in deducing, from the identity of their composition in 100 parts.

How are the elements of

The question, in what way the elements of fibrine, albumen, and caseine are arranged, is one of the these compounds arranged?

most interesting and important in Animal Chemistry. These three bodies contained (at that time this was still believed in the case of fibrine) an equal amount of carbon, nitrogen, hydrogen, and oxygen, while there was great difference in their physical properties. But we had been long familiar with groups of compounds, which, with a perfect identity of composition, exhibit the most marked differences in their properties; this supposed identity of composition was not, therefore, surprising. In all isomeric substances, more exact research had demonstrated, that their elements were differently arranged, and that, consequently, their chemical constitution was to the full as different as were their physical properties. Although their composition in 100 parts was the same, yet their atomic weight, or the products of their decomposition, or their density in the state of vapour, was different; the variation in their chemical constitution corresponded to that of their physical properties.

Isomeric compounds long known.

But isomerism was not supposed to furnish the explanation here.

What, now, according to these previous observations, was the cause of the great dissimilarity in the properties of the above-mentioned animal substances? If their elements were differently arranged, or the products of their decomposition or transformation different, this formed, of course, no obstacle to the probable conversion of one into the other, of caseine or fibrine into albumen, or of albumen into caseine and fibrine, since the study of isomeric substances had taught us, that in many cases, even where the difference of chemical constitution was very great, such transformations of one into another actually occur. All this was left unexplored. The chemist who first entered in this field of research, which promised so abundant a harvest, assumed, on the strength of the most defective experiments, that in these three substances the four above-named elements were combined, exactly in the same way in all, to form a group, which group constituted a distinct substance, capable of being isolated, to which the name of *proteine* was given. *Assuming the chemical constitution of this group* as the same in all three bodies, what was now the origin of so great a difference in properties as they presented? The cause of this difference was sought for in a fifth element, or in a second group.

All these substances were supposed to contain a group of elements,

called *proteine,*

It was found, namely, that all these animal substances contain a certain amount of *sulphur*; it was assumed, that some of them contained also a certain amount of *phosphorus*; and the variation in their properties was ascribed to the presence of this sulphur, or sulphur and phosphorus. (The existence of phosphorus, as an essential element of these substances, has not, however, been in any way established.) *In this way an organic radical, or a body* analogous to organic radicals, was created; a body formed by the combination of twelve hundred elementary atoms, a group of twelve hundred atoms, the physical character of which was determined by the addition of one or more atoms of sulphur, or of

combined with various proportions of sulphur and phosphorus,

although they were not shown to contain phosphorus.

sulphur and phosphorus. To support this view, a property was imagined, which a compound of sulphur could not possibly exhibit. The sulphur, which in these compounds caused such striking differences, was as loosely combined with the proteine, as we find it in a mixture of iron filings or sawdust with sulphur. It was supposed, that when these substances are acted on by an alkali, the sulphur was detached from the proteine, just as easily as if it had not been combined with it; it dissolved in the form of sulphuret of potassium and hyposulphite of potash; the proteine was thus set free, and dissolved also in the excess of alkali; and when this alkaline liquid was neutralised by an acid, the fundamental constituent of these animal substances, the proteine, was obtained in the form of a gelatinous precipitate. The idea of the sulphuret, or of the sulpho-phosphuret, of proteine, led at once to a series of oxides of proteine, to a multitude of imaginary substances, to which was now ascribed, as of old to phlogiston in chemical processes, the function of determining and effecting all the changes which occur in the vital process.

Supposed oxides of proteine, &c.

Let us now see to what truths this supposition has led, and how it explains the differences in the properties of the animal substances. In the latest work of Mulder above quoted (p. 316), the constitution of the proteine compounds is represented as follows:

Composition of animal substances according to Mulder.

Crystalline humour	contains for	15 eq.	Proteine	1 eq.	Sulphur	
Caseine	,,	10	,,	1	,,	
Vegetable gelatine	,,	10	,,	2	,,	
Albumen of eggs	,,	10	,,	1	,,	& 1 eq. Phosphorus
Fibrine	,,	10	,,	1	,,	1 ,,
Albumen of blood	,,	10	,,	2	,,	1 ,,

We have now reached the ultimate object of this theory; and the question, What insight has it afforded? is answered by a glance at the above table.

Albumen of blood said to differ from albumen of eggs,

The albumen of the blood, the properties of which coincide so closely with those of the albumen of eggs, chemically as well as physically, contains twice as much sulphur. Here, similarity of properties *accompanies a difference in composition; and from* this we can draw no other conclusion than this, that the sulphur, the amount of which varies, has no influence on these properties.

while fibrine has the same composition as albumen of eggs.

But what is the cause of the great difference between the properties of fibrine and those of the albumen of eggs? Is it sulphur or phosphorus? *No. These substances contain* (according to Mulder) *the same quantities of proteine, sulphur, and phosphorus.*

Such views constitute no real progress.

Such is the progress which Animal Chemistry has made in eleven years in regard to the chemical constitution of the blood constituents; we know as much of it now, as we did forty years since; not to mention that the assumption of the presence of phosphorus in albumen and fibrine, an assumption resting on the most frivolous experiments, renders the explanation of the transformation of the caseine of milk into blood utterly impossible.

Sulphur exists in

Any one who will take the trouble to prepare two forms in animal substances;

the so-called proteine according to the directions of Mulder, must immediately perceive that sulphur is contained in fibrine, albumen, and caseine in two distinct forms of combination.

in the form in which it occurs in cystine

and in taurine.

If we suppose these bodies to consist of several groups of atoms, of which groups two contain sulphur, the action of alkalies on them points out that the sulphur in one of these compounds exhibits the same relations as the sulphur in cystine; the sulphur of this compound combines with potassium, while it is replaced by the oxygen of the potash; but the other compound of sulphur remains unchanged, and its sulphur exhibits the relations of that contained in taurine. We observe, moreover, that the former (the more easily decomposed) of these sulphur compounds preponderates in the albumen of the blood; the latter in caseine.

Any one who reads the note which I published thirteen months ago in the "Annalen der Chemie und Pharmacie" (vol. lvii. p. 133), on these questions, will admit, that it was impossible to use greater forbearance in pointing out to the author of the proteine theory the error into which he had fallen than I then did, while I afforded him the opportunity of repeating his experiments. The result, however, was the publication of his recent pamphlet, a work which I shall not further notice, preferring to leave the facts, as now ascertained and generally admitted, to speak for themselves.

Results of recent re-

It now appears, as the result of the more accurate investigations of Laskowski, Rüling, Verdeil, Walther, and Fleitmann, that the amount of sulphur present in the blood constituents is three times, in many cases four times, as great as the apparently well established analyses of the author of the proteine theory had indicated. It further appears, that a body, destitute of sulphur, and having the composition of proteine, is not obtained by the methods given by Mulder; that fibrine differs in composition from albumen; that the albumen of eggs contains not less, but more sulphur than the albumen of the blood, which sufficiently explains the disengagement of sulphuretted hydrogen in the experiments made with the former on artificial digestion. The study of the products, which caseine yields when acted on by concentrated hydrochloric acid, of which, as Bopp has found, Tyrosine and Leucine constitute the chief part, and the accurate determination of the products which the blood constituents, caseine, and gelatine, yield when oxidised, among which the most remarkable are oil of bitter almonds, butyric acid, aldehyde, butyric aldehyde, valerianic acid, valeronitrile, and valeracetonitrile, have opened up a new and fertile field of research into numberless relations of the food to the digestive process, and into the action of remedies in morbid conditions; discoveries of the most wonderful kind, which no one could have even imagined a few years ago; and the investigation which I now proceed to describe, will, I trust, contribute to excite the hopes of che-

searches. Larger amount of sulphur present.

Proteine cannot be obtained by Mulder's *methods.*

Products of the decomposition of *caseine*, gelatine, and the blood constituents.

mists and of physiologists, and encourage them to direct their efforts, more than they have hitherto done, towards this department of science.

SECTION II.

On the Constituents of the Juices of Flesh.

Acid reaction of the juices of flesh.

It has long been known that the flesh of newly-killed animals reddens blue litmus paper, while nothing certain is known as to the nature of the free acid which causes this reddening. Berzelius, in his detailed investigation of the juice of flesh, observes on this subject as follows :*—

Opinions of Berzelius.

" When the liquid " (obtained by pressure from the muscular substance) " out of which the albumen " and the colouring matter have been coagulated, " is evaporated after filtration, it leaves a yellowish " brown extract, of which alcohol takes up the half or " more with a yellow colour. After the evaporation " of this solution there is left an extract-like mass, " mixed with crystals of common salt, which has a " strong acid reaction, and notwithstanding leaves " on incineration an ash containing an alkaline carbonate, thus proving that the mass contained an " organic acid, partly free, partly combined with " alkali. If the alcoholic solution be mixed with a " solution of tartaric acid in alcohol, potash, soda, " and lime are deposited in the form of tartrates, and

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* Handbuch, vol. ix. p. 573.

" there remains in the alcoholic solution, along with " tartaric and hydrochloric acids, a combustible acid " dissolved. The solution is digested with finely-" divided carbonate of lead, till lead is detected in " the liquid; it is then evaporated, the lead preci-" pitated by sulphuretted hydrogen, the acid liquid " boiled with animal charcoal and evaporated. It " leaves a colourless, very acid syrup, possessing all " the characters of lactic acid, but still retaining a " portion of extractive matter mixed with it."

This is essentially the amount of all that is known in regard to the nature of the free acid present in the muscles.

In his researches on urine and on milk, Berzelius, by employing a similar process, obtained also strongly acid extractive substances, the properties and chemical relations of which he explained by the presence of lactic acid.

Is lactic acid present?

Whether these statements can at the present time be regarded as proofs of the existence of lactic acid, that is, of the acid now called by that name, will be best seen from the opinions which Berzelius entertained concerning the nature of lactic acid, both at the time when his researches were made (1807), and subsequently (1823 and 1828).

Earlier and later views of Berzelius as to the nature of lactic acid

On the occasion of his report on Daniell's lampic acid, Berzelius observes,* " These researches render " it very probable that the lactic acid, which occurs " so frequently in the animal kingdom, and which I

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* Jahresbericht, Jahrgang ii. p. 72.

"have endeavoured to prove in a former work to "be different from acetic acid, is likewise nothing

in 1807, "more than a similar combination of acetic acid

1823, "with a peculiar animal substance, which accompa-"nies it in its salts, is the cause of the differ-"ences between these salts and the acetates, and "moreover prevents the volatilisation of the acid, "as long as the foreign matter is not destroyed. "A further inducement to adopt this opinion is "derived from the circumstance, that concentrated "lactic acid, when neutralised with caustic ammonia "and heated, yields distinctly vapours of acetate of "ammonia, becoming acid at the same time."

1828, In the seventh yearly volume of his Jahresbericht, Berzelius again observes, in considering Tiedemann and Gmelin's important researches on digestion, on the occasion of their mentioning acetate of potash as an ingredient of saliva (p. 200), "They" (Tiedemann and Gmelin) "assume, on the "authority of Fourcroy and Vauquelin, as well as of "their own experiments, and, as they say, of mine "also, that lactic acid is only acetic acid, rendered im-"*pure by the presence of an animal matter.* I have "certainly made experiments with the purpose of "resolving lactic acid into acetic acid and a foreign "substance; but I am not aware that I have ever "succeeded in doing so; and as long as we cannot "obtain acetic acid from it without destructive "distillation, or as long as lactic acid cannot be "formed from acetic acid and an animal substance,

" so long it is best to retain the name of lactic acid; " for if lactic acid be a chemical compound of acetic " acid with an animal substance, which enters into " the composition of the salts, and deprives the acetic " acid of its volatility, it would be as inaccurate to " call these salts acetates, as to call the sulphovi- " nates or nitroleucates sulphates or nitrates."

and 1832.

In his last investigation on this subject,* Berzelius describes some experiments, from which it might be concluded that lactic acid contains no acetic acid, *and he terminates his researches with the following* words:—" Future investigations must be chiefly " directed to ascertain, whether that which has been " called lactic acid be a mixture of two acids, which " resemble each other, but yet yield different salts."

The true nature of lactic acid only ascertained of late years.

From these passages it is evident, that, at the time when chemists began to reckon lactic acid among the ingredients of the fluid of the muscles, the properties of the acid now known by that name were almost entirely unknown: so much so that the acid discovered by Braconnot, which is formed in rice-water and in the juice of beet-root, was considered as a peculiar acid, till L. Gmelin proved it to be identical with the acid of sour milk, and C. Mitscherlich described his method of obtaining lactic acid from sour milk in a state of purity.

The former evidence of the presence of lactic acid in the body is

It is plain that the assumption of the existence of lactic acid in the animal body, founded, forty years ago, on grounds so uncertain and variable, could no

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* Annalen der Pharmacie, vol. i. p. 1. 1832.

no longer sufficient,

longer be admitted in our day, more particularly as no chemist, after Berzelius, has occupied himself with a more exact study of the subject, or has attempted to prove that the acid of the muscles is identical with that of sour milk. This identity, or indeed the presence of a non-nitrogenised organic acid as an ingredient of the living body, was rendered still more doubtful and improbable, when the accurate investigation of urine, in which lactic acid was said to be present, had proved the absence of it in that fluid.

especially as it has been shown not to exist in urine.

What is the acid of the gastric juice?

I regarded the determination of the nature of the acid diffused through the chief mass of the body, as the more important, that this alone could give us an explanation of the nature and origin of the acid which takes a share in the digestive process. The acid of the gastric juice is not formed during digestion from the ingredients of the food, which in themselves are not acid, but is secreted from the lining membrane of the stomach even in the fasting state. If this acid were an ingredient of the blood, then it must admit of being detected in the blood or in some other part of the body.

Supposed by some, on very defective evidence, to be lactic acid.

Several French chemists, resting their conclusions on qualitative researches, have indeed stated that the acid of the gastric juice is lactic acid; but the reactions, which were held to prove the presence of lactic acid, either do not belong to that acid,* or are such as lactic acid possesses in common with

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* See Annalen der Chemie und Pharmacie, vol. lxi. p. 216.

other acids, particularly with phosphoric acid, which is never absent in animal fluids.

Kreatine discovered by Chevreul.

In 1835, Chevreul described, as an ingredient of the liquid obtained by boiling flesh with water, a new substance, under the name of *Kreatine* (from κρεας, flesh), which was distinguished by its properties from all known compounds. He obtained it in very small quantity by acting with alcohol on the residue obtained by evaporating the soup *in vacuo*.

His account of its properties.

The properties of kreatine, as observed by this distinguished chemist, are as follows: "Kreatine is "distinguished by the transparency of its crystals, "which are right-angled prisms of mother-of-pearl "lustre; it is heavier than nitric acid of sp. g. 1·34 "and lighter than sulphuric acid of sp. g. 1·84. It "has no action on vegetable colours; its solution in "water is not precipitated by chloride of barium, "by oxalate of ammonia, nitrate of silver, sulphate "of copper, protosulphate of iron, subacetate of "lead, or bichloride of platinum. 1,000 parts of "water at 15° C. (64° F.) dissolve 12·04 parts of "kreatine; alcohol of sp. g. 0·804 dissolves about "$\frac{1}{2000}$th of its weight. Its solution in nitric acid, "when warmed, gives off nitrous acid, and leaves "on evaporation a residue, which gives a precipitate "with chloride of platinum, and deposits small "granular crystals. Kreatine dissolves in hydro-"chloric acid: the solution gives on evaporation "colourless dendritic crystals, which do not precipi-"tate bichloride of platinum.

"In its aqueous solution, kreatine is spontaneously although slowly decomposed, there is "observed a distinct odour of ammonia along "with a heavy, mawkish smell; the liquid loses its "transparency.

"When heated in a small tube, kreatine decrepitates, gives off water, becomes opaque and dull, "then melts without becoming coloured, and is finally "decomposed, ammonia being disengaged, along "with a smell of hydrocyanic acid and phosphorus. "There is condensed in the upper part of the tube "a yellow vapour, partly in the liquid state, partly "in the form of crystals. The carbonaceous residue "is trifling, and leaves on incineration a mere trace "of ashes, which contain no chloride of sodium.

"Kreatine contains water of crystallisation, which "is expelled by a heat of 212°; its ultimate elements are carbon, hydrogen, nitrogen, and oxygen, "in proportions not yet ascertained." (Journal de Pharmacie, vol. xxi. p. 236.)

Opinion of Chevreul as to its nature.

Chevreul compares this substance with asparagine, and shows that it cannot be confounded with that substance. He adds that kreatine, when acted on by baryta, yields an acid very different from aspartic acid. "Perhaps," he says, "it is an ammoniacal "salt, formed by the combination of ammonia with "an organic acid."

Berzelius endeavours to obtain it.

After Chevreul had published his observations on the occurrence of kreatine, several chemists endeavoured again to obtain this substance. Berzelius observes on this subject, in his "Handbuch," that "After the discovery of Chevreul became known, I "tried in vain to prepare this substance from "raw beef. Meantime I have had an opportunity "of seeing kreatine in the possession of that distinguished chemist. It would appear, there"fore, rather to be an accidental ingredient, the "presence of which depends on peculiar circum"stances in the feeding of the cattle, and which "therefore is sometimes present and at other times "absent. If, accordingly, it should be found in the "liquid in which beef has been boiled, it would "evidently be the product of a metamorphosis." Wöhler observes, in a note on this passage, "I have "obtained this substance from the soup of 8 lbs. of "beef, in yellowish crystals. It is not allantoine, "as I suspected it might be."

His opinion.

Wöhler obtains it. It is not allantoine.

Schlossberger, in his examination of the muscles of the alligator,* says, "The aqueous extract of the "flesh, heated to coagulate the albumen, filtered, "and evaporated in the water-bath, yielded a "brownish-yellow syrup, pretty strongly acid, with "an odour of roast meat, such as is understood "under the term Osmazome, as obtained from ordi"nary flesh. Hot alcohol dissolved a considerable "part with a yellow colour, and deposited on cool"ing small cubical yellowish crystals, which may be "washed with water, or better with alcohol. Thus "purified, they had all the characters of Chevreul's

Schlossberger finds it in the flesh of the alligator.

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* Annalen der Chemie und Pharmacie, vol. xlix. p. 343.

" kreatine. When heated, they become white and " opaque, then melt, giving out a yellow vapour and " an ammoniacal empyreumatic odour, leaving a " coal, which, after long ignition, leaves a mere " trace of ashes. Heated with nitric acid on the " platinum spatula, they caused, for an instant, on " the addition of ammonia, a rich yellow colour, soon " passing into brown. They dissolved in strong " nitric acid with the evolution of yellow vapours, " and the solution, when evaporated, left a white " residue. The aqueous solution of the crystals is " not precipitated by nitrate of silver, subacetate of " lead, or salts of baryta. Unfortunately the quantity in my possession was not sufficient for an " elementary analysis, since from several pounds of " flesh I only obtained 0·15 gramme (2·3 grains). " At all events," continues Dr. Schlossberger, " it " is desirable to recommence the search for this " singular substance, which Chevreul discovered in " the soup of the Dutch Company, but which Berzelius and Simon could not obtain. I myself was " also unable to detect it in my numerous analyses of " flesh in 1838, although I expressly sought for it. " Wöhler has obtained a small quantity from ox flesh, " and has determined that it is not allantoine. It " would appear therefore either not usually to occur " in the substance of the muscles, or to occur in so " small a quantity that it cannot be detected. However this may be, the detection of this substance, so " well characterized by its tendency to crystallise

Schlossberger's opinion.

" and its whole chemical character, in the flesh of " animals so widely separated as the ox and the " crocodile, must be regarded as a fact worthy of " attention."

Results of preceding researches on flesh.

This is the essential part of all that is known from previous researches in regard to lactic acid and kreatine as ingredients of flesh. With respect to the other substances which are spoken of in chemical works as ingredients of flesh, I believe I need make no further quotations, since their intimate chemical relations are entirely unknown, and they offer no remarkable peculiarities beyond the facts that they are precipitated by acetate and subacetate of lead, by corrosive sublimate, tannic acid, or chloride of tin.

The author succeeds in obtaining kreatine,

In the early part of my investigation I succeeded, after many fruitless attempts, in obtaining a small quantity of kreatine from the juice of the flesh of fowls, and the study of its chemical relations soon showed, that this substance, during the evaporation of the fluid, loses its power of crystallising, in consequence of a change which it undergoes under the influence of the free acid present in the solution, and that in this way its purification and preparation are rendered much more difficult. The separation of the non-nitrogenised acid, which I soon found to be present in the juice of flesh, was at first attended with no small difficulties, and ultimately it is only the more exact acquaintance with the other substances occurring in this fluid, which has led to the simple methods of preparing and separating them,

and in devising simple methods of obtaining the constituents of flesh.

to be described in the following pages in the order in which they present themselves to the observer.

Flesh extracted by water.

When the finely minced flesh of newly-killed animals is extracted by water, there is obtained a red or reddish coloured fluid, having the taste which is peculiar to the blood of different classes of animals. If this fluid be heated in the water-bath, the albumen, as Berzelius has observed, coagulates first, and the liquid retains its red colour. The albumen at first separates as a nearly colourless coagulum, which afterwards collects in denser flocculent masses, and the colouring matter is only separated at a considerably higher temperature. It is easy to observe the point at which the albumen has been entirely coagulated, while the red colouring matter still remains in solution. It is now only necessary to bring the liquid into actual ebullition in a silver or porcelain vessel, in order to separate the whole of the colouring matter in the coagulated state, and we thus obtain a liquid easily filtered, which reddens litmus powerfully. The coagulated albumen, as well as the undissolved fibrine and cellular tissue, have also an acid reaction, which cannot be removed by washing with water. The insoluble residue of the flesh (fibrine, cellular tissue, &c.), when boiled with water, becomes opaque, milk-white, of horny hardness, and the water acquires by dissolving gelatine the property of gelatinising on cooling, when sufficiently concentrated.

Albumen and colouring matter coagulated by heat.

The filtered liquid is acid.

A good

If we desire to obtain the soluble constituents of the muscular substance without great loss, and without using inconveniently large quantities of water, a good press is indispensable. We can, it is true, by the process I am about to describe, obtain with ease each of the substances mentioned, but to this end it is not advisable to operate on less than from 8 to 10 lbs. of flesh. It is only necessary to reflect that flesh contains from 76 to 79 per cent. of water, and from 2 to 3 per cent. of soluble albumen, and that after extraction with water there are left from 17 to 18 per cent. of fibrine and other insoluble matters, in order to perceive that even when we employ 10 lbs. and upwards of flesh we are still operating on comparatively small quantities of the soluble constituents. (On the average, the soluble matter of 10 lbs. of flesh, after the coagulation of the albumen and colouring matter, does not exceed 4 oz., and of this a very considerable proportion consists of inorganic salts, the phosphates being particularly abundant, while the remainder is formed of not less than five organic compounds.)

press is indispensable.

Small proportion of soluble matter in flesh.

8 or 10 lbs. of flesh should be used.

Supposing that 10 lbs. of flesh are to be operated upon, the half of this quantity is taken, and covered with 5 lbs. of water. The mixture is carefully kneaded with the hands, and is then pressed as completely as possible in a bag of coarse linen. The pressed residue is a second time carefully kneaded with 5 lbs. of water, and again pressed. The fluid of the first pressing is set aside for further operations, that of the second being used for the first

Best mode of extraction.

extraction of the second half of the flesh. In like manner the residue of the first half is a third time treated with 5 lbs. of water, and the expressed fluid serves for the second extraction of the second half, which is finally extracted a third time with pure water, in which it is allowed to soften, and again pressed out.

Coagulation of the albumen and colouring matter.

The united liquids are passed through a clean cloth to separate any fragments of muscular fibre, and then introduced into a large glass globe, which is placed in a pan of water, the latter being gradually heated to the boiling point, and kept at this temperature till the liquid has lost its colour, and the whole of the albumen and colouring matter have separated in a coagulum. When a portion, heated to boiling in a test tube, remains clear, and deposits no flocculi, this operation is completed.

All visible fat should be removed.

In many kinds of flesh, it is necessary, in order to separate the last traces of colouring matter after the coagulation of the albumen, to remove the liquid from the globe, and bring it into actual ebullition in a silver or porcelain vessel, which is so much the more easily done that the adhesion of the coagulum to the bottom of the vessel, where it would be singed or burnt, is no longer to be dreaded. It is moreover advisable, to remove all visible fat as completely as possible from the flesh, or to select the flesh of lean animals, because the fat very much impedes both the extraction of the flesh with water and the pressing of the mass. When fat flesh is used, the cloths or bags in which it is pressed become quickly useless, their pores being clogged with fat.

Characters of the liquid filtered from the coagulum.

The liquid, after the coagulation of the albumen and colouring matter, is strained through a cloth, the coagulum pressed, and the united liquids filtered.

The colour of the filtered liquid varies with the kind of flesh. That from flesh very full of blood, as is that of the ox, roe-deer, hare, and fox, has a reddish colour; while that from veal and fowl, as well as that from fish, is hardly coloured.

For the preparation of kreatine, the flesh of wild animals and of common fowls is the best adapted. The liquid obtained from these kinds of flesh is, when filtered, clear and limpid; that of the horse and of fish is always turbid; the taste of all is nearly the same, and the fluid from the flesh of the fox is in this respect not distinguishable from that derived from lean beef. The fluid from the flesh of the marten possesses a distinct musky smell, which becomes more decided when it is heated and evaporated.

The liquid is always acid,

All the different fluids obtained by the above process have an acid reaction, which appears to me the more worthy of notice, that, in the case of the ox, sheep, and game, it can only be obtained mixed with a proportionally large quantity of blood; and yet the alkali contained in the blood, on which its alkaline reaction depends, is yet not sufficient to neutralise the free acid present in the fluid of the flesh. Indeed, I believe that in most animals, if we suppose the whole mass of blood in the vessels to be mixed with the whole fluid of the muscles, the mixture would retain, not a neutral or alkaline, but an acid reaction. In the hare, the amount of whose blood is proportionally small, this is certainly the case.

and does not become neutral when the blood is added to it.

The acid liquid by evaporation becomes brown, and yields few crystals.

If the clear liquid, as obtained by filtration, be concentrated over the open fire, even without being heated to the boiling point, it becomes gradually darker in colour, and at last leaves a dark brown syrup, with a smell of roast meat, in which traces of kreatine in crystals only appear after it has stood for a long time. The brown colour is in part caused by the formation of a deposit of dissolved matter, which attaches itself to the bottom of the vessel, and in consequence of the higher temperature to which it is there exposed, passes into a dark soluble substance; but even when this deposit is avoided, as, for example, when the evaporation is conducted in the water-bath, the dark colour infallibly appears. The chief cause of it, besides the temperature, is the presence in the liquid of free acid, which must be removed before evaporation.

The acid must be removed

by the addition of baryta.

To this end there is added to the liquid a concentrated aqueous solution of baryta, as long as it produces a white precipitate. After a certain quantity of baryta has been added, the liquid becomes neutral or even alkaline, but this must not prevent us from adding it as long as it causes the slightest turbidity in a filtered portion of the liquid.

Phosphates are precipitated.

The precipitate thus formed consists of phosphate of baryta, and phosphate of magnesia, and contains none of the double phosphate of ammonia and magnesia; nor is ammonia disengaged by the addition of baryta. In one operation alone, out of many, was a distinct separation of ammonia observed.

No ammonia is disengaged,

and no sulphates are found in the precipitate.

The precipitate from the liquid derived from the flesh of fowls dissolves in diluted hydrochloric acid without residue; and in those cases in which sulphate of baryta remains undissolved, its quantity, compared with that of the flesh, is so trifling, that we may ascribe with perfect certainty the sulphuric acid thus indicated to the mixture of a little blood.

The filtered liquid must be gently evaporated.

After the separation of the precipitate, which contains the whole phosphoric acid of the fluid of flesh, the filtered liquid is divided into flat porcelain dishes, and concentrated in the water-bath or sand-bath, taking care that it never boils. If the upper edge of the evaporating dish be allowed to become hotter than the liquid, a portion is always dried up on this part, forming a dark brown ring, which, on the addition of fresh liquid, dissolves in it without perceptibly colouring it; but in this case the colour comes out when the liquid is concentrated. When the liquid from fowls' flesh, after the action of baryta, is evaporated, it continues perfectly clear, only if an excess of baryta has been added, a film of carbonate of baryta forms on the surface.

In the evaporation of the same fluid from beef, there is formed, when it has acquired a syrupy consistence, a mucilaginous skin on the surface, which, when divided in water, swells up without dissolving. In the case of the flesh of the calf and of the horse, these skins or membranes succeed each other continually; they may be removed as coherent membranes, and they must be taken away as often as their formation is repeated.

A skin formed in some cases during evaporation.

When the fluid has been reduced to about $\frac{1}{20}$ of its original volume, and has acquired a thickish consistence, it is placed in a moderately warm situation, and left to evaporate slowly. Very soon small, distinct, short, colourless needles appear on the surface, which increase on standing, and on cooling, so that the walls of the vessel are gradually covered with them.

The concentrated liquid deposits kreatine in crystals.

These crystals are kreatine.

The process thus described applies to all the different kinds of flesh above mentioned, except that of fish, for which a modification of it is required.

The flesh of fishes, when finely minced, cannot be pressed; it swells up with water to a mucilaginous mass, which clogs up the pores of the cloth. We have, therefore, no choice but to mix it with twice as much water as above recommended, to throw the mixture on a funnel, and to displace the fluids by repeated affusion of small quantities of water. The infusion is colourless, slightly opalescent, has an

Modification of the process for fish.

acid reaction and a very marked taste and smell of fish. When heated, it yields a perfectly white, soft coagulum, and after the addition of baryta, when evaporated and allowed to cool, yields a colourless jelly, in which, when allowed to rest, very distinct and regular crystals of kreatine form after twenty-four hours.

Proportion of kreatine in different kinds of flesh.

The quantity of kreatine, obtained from different kinds of flesh, is very unequal. Of all kinds, the flesh of fowl and that of the marten contain the most, then that of the horse, the fox, the roe-deer, the red deer and hare, the ox, pig, calf, and finally that of fishes.

It is greater in wild than in confined animals.

The variation in the amount of kreatine is striking even in animals of the same class. The flesh of a fox, fed on flesh for two hundred days in the anatomical rooms at Giessen, did not yield so much as the tenth part of the quantity of kreatine obtained from foxes killed in the chase.

Its amount bears a relation to that of fat.

The amount of kreatine in the muscles of an animal stands in an obvious relation to that of fat, or to the causes which determine the deposition of fat. From fat flesh there are often obtained mere traces of kreatine, and always much less than from lean flesh, for the same amount of muscular fibre. The fox above mentioned, which had been fed, yielded more than 1 lb. of fat from the omentum, while in foxes hunted or shot hardly any fat was visible.

Actual amount of

From 100 lbs. (Hessian) of the flesh of an old, kreatine obtained by the author.

lean horse, there were obtained nearly 36 grammes (555 grains) of kreatine. 116 lean fowls yielded about 72 grammes (1,110 grains); and 86 lbs. of beef 30 grammes (463 grains).

The weight of the flesh of a fowl was, on an average 203 grammes (3,134 grains, or about 7 oz. avoirdupois); that of wild foxes weighed from 2 to 2½ lbs. (Hessian).*

Kreatine found in all the higher classes of animals.

I have found, as already stated, kreatine in the flesh of the ox, sheep, pig, calf, roe-deer, hare, marten, fox, red deer, common fowl, and fish; and as it cannot be doubted that the crystals obtained by Schlossberger from the flesh of the alligator were also kreatine, it may fairly be concluded that this substance is an ingredient of the muscles of all the higher classes of animals.

It is not to be

I have not been able, by the same process, to

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* *Note by the Editor.*—The figures in the text, when reduced to 1000 parts, indicate that

1000 parts of the flesh of Fowl yielded 3·05 kreatine (crude ?)
1000 „ the Horse „ 0·72 „
1000 „ the Ox „ 0·697 „

In one experiment I obtained from the flesh of eight fowls, weighing hardly 3½ lbs., 78·75 grains of purified kreatine, or 3·21 parts from 1000. A second experiment, with the same quantity of flesh, yielded 71 grains of pure kreatine, or 2·9 parts in 1000. Not having been provided with a proper press, considerable loss was unavoidably sustained in both these experiments, which were also made on a smaller scale than is recommended in the text. The average of the two agrees exactly with the result obtained by the author, namely, from fowl 3·05 parts in 1000.—W. G.

detect kreatine in the substance of the brain, of the liver, or of the kidneys; but it is present in abundant quantity in the heart of the ox, so that this organ is especially adapted for its preparation. The study of the substance of the brain and liver presented a number of peculiarities, which promise valuable results on a closer investigation. Thus, for example, when the substance of the brain is rubbed with barytic water to a thin emulsion, passed through a fine hair-sieve, and heated to boiling, there is obtained a coagulum, in which is contained all the fat of the brain, and a clear yellowish liquid, which when deprived of the excess of baryta by a current of carbonic acid gas, and subsequent boiling, contains two salts of baryta, one of which is soluble in alcohol. Both are soluble in water, and give with acids a white flocculent precipitate.

found in the brain, liver, or kidneys, but the heart contains it.

Peculiarities worthy of investigation in the brain and liver.

Kreatine.

The crystals of kreatine, obtained as above described, are separated from the mother liquid by a filter, washed, first with a little water, then with alcohol, and dissolved in boiling water. If the solution should be coloured, some animal charcoal (from blood) is added, and a very small quantity is sufficient to give a liquid which, when filtered, is colourless and limpid, and which, on cooling, deposits the kreatine in perfectly pure crystals.

Purification of kreatine.

If the phosphoric acid has not been entirely removed by means of baryta, then the original crystals are mixed with phosphate of magnesia, of which the greater part is left behind on recrystallisation; but a small portion dissolves and is deposited along with the crystals of kreatine. To remove this impurity, the filtered solution is boiled with a little hydrated oxide of lead, filtered, and then treated with a little animal charcoal, which absorbs the traces of oxide of lead that may have been dissolved.

Description of the crystals.

The crystals of kreatine are colourless, perfectly transparent, and of the highest lustre; they belong to the klinorhombic system, and form groups, the character of which is exactly similar to that of sugar of lead. At 212°, the crystals become dull and opaque, with loss of water.

Analysis of kreatine.

0·485 gramme of crystallised kreatine lost at 212°, 0·059 gramme of water = 12·16 per cent.

0·3582 gm. of crystallised kreatine lost at 212°, 0·044 gm. of water = 12·28 per cent.

0·5835 gm. of crystallised kreatine lost at 212°, 0·0705 gm. of water = 12·08 per cent.

0·603 gm. of crystallised kreatine lost at 212°, 0·0753 gm. of water = 12·18 per cent.

Hence 100 parts lost, on an average, at 212°, 12·17 parts of water of crystallisation.

The combustion of dried as well as of crystallised kreatine with oxide of copper, yielded a gaseous mixture which contained, for 388 volumes of nitrogen, 1,036 vol. of carbonic acid. Hence kreatine contains, for 8 vol. of carbonic acid or 8 eqs. of carbon, 3 vol. or eqs. of nitrogen.*

Further, in combustion with chromate of lead,—

0·5628 gm. of crystallised kreatine yielded 0·6764 gm. of carbonic acid. (The water was lost in this analysis.)

0·5830 gm. of crystallised kreatine yielded 0·693 gm. of carbonic acid, and 0·388 gm. of water.

0·545 gm. of crystallised kreatine yielded 0·658 gm. of carbonic acid, and 0·367 of water.

0·2884 gm. of crystallised kreatine yielded 1·300 gm. of the double chloride of platinum and ammonium, = 28·32 per cent. of nitrogen.

These analyses yielded, for 100 parts of kreatine:

	I.	II.	III.
Carbon	32·77	32·91	32·41†
Nitrogen	28·32	28·32	28·32
Hydrogen	,,	7·33	7·39
Oxygen	,,	31·44	31·88
		100·00	100·00

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* The 2nd tube gave for 89 vol. nitrogen 217 vol. carbonic acid.

3rd	,,	64	,,	156	,,
4th	,,	78	,,	219	,,
5th	,,	77	,,	224	,,
6th	,,	80	,,	220	,,
Total	,,	388	,,	1036	,,

† In combustion with chromate of lead, it is well known that the formation of nitrous acid is unavoidable, and the excess of carbon in the above analysis arises, no doubt, from a small quantity of nitrous acid which had escaped the reducing action of the metallic copper in the anterior part of the tube.

corresponding to the formula,

Formula.

8 eq. Carbon	48	32·22
3 eq. Nitrogen	42	28·19
11 eq. Hydrogen	11	7·38
6 eq. Oxygen	48	32·21
Atomic weight of crystallised Kreatine	149	100·00

Anhydrous kreatine.

0·3145 gm. of anhydrous kreatine yielded, when burned with oxide of copper, 0·4195 gm. of carbonic acid, and 0·197 gm. of water.

0·4085 gm. of anhydrous kreatine, burned with chromate of lead, yielded 0·5590 gm. of carbonic acid, and 0·2348 gm. of water.

These analyses give in 100 parts (C : N = 8 : 3):

	I.	II.
Carbon	36·38	36·93
Nitrogen	31·91	32·39
Hydrogen	6·96	6·96
Oxygen	24·75	23·72
	100·00	100·00

corresponding to the formula,

Its formula.

8 eq. Carbon	48	36·64
3 eq. Nitrogen	42	32·06
9 eq. Hydrogen	9	6·87
4 eq. Oxygen	32	24·43
Atomic weight of anhydrous Kreatine	131	100·00

The crystallised kreatine corresponds, therefore, to the formula,

Formula of the crystals.

1 eq. anhydrous kreatine	131	87·92
2 eq. water	18	12·08
	149	100·00

If we compare the formula of kreatine with that of glycocoll (sugar of gelatine), it appears that crystallised kreatine contains the elements of, Kreatine and glycocoll.

$$\begin{array}{lcl} \text{2 eqs. glycocoll} & = & C_8\ N_2\ H_8\ O_6 \\ +\ \text{1 eq. ammonia} & = & \quad N\ H_3 \\ \hline & & C_8\ N_3\ H_{11}\ O_6 \end{array}$$

Kreatine dissolves easily in boiling water, and a solution saturated at 212° forms, on cooling, a mass of small brilliant needles. From a diluted solution it crystallises very slowly, in somewhat large crystals, often from 2 to 3 lines in length and 1 line in thickness, which increase in size for 24 hours after cooling, if left in the liquid. Properties of kreatine.

1,000 parts of water at 64·4° dissolve 13·44 parts of kreatine; or 1 part of kreatine dissolves in 74·4 parts of water.

In cold alcohol kreatine is nearly insoluble, 1 part requiring 9,410 parts of alcohol for solution. In weaker spirits of wine it is rather more soluble.

The cold aqueous solution of kreatine possesses, from the small quantity of dissolved matter, a weak, bitter taste, followed by a somewhat acrid sensation in the throat. When the aqueous solution of kreatine contains a trace of foreign organic matter, it decomposes very readily, as Chevreul observed. Mouldy vegetations appear, and the liquid acquires an offensive, nauseous odour.

No quantity, however large, of kreatine can destroy the acid reaction even of the weakest acids; Kreatine is neither acid nor basic. it possesses no basic characters. It dissolves easily with the aid of heat in barytic water, and crystallises from it unchanged. The crystals which are deposited contain no baryta, and all the baryta in the solution is precipitated by carbonic acid. But when boiled with baryta water, kreatine is decomposed; ammonia is disengaged; the liquid becomes turbid, even when the air is entirely excluded, and there is deposited carbonate of baryta in crystalline grains, the quantity of which progressively increases as the boiling is continued.

In the warm saturated solution of kreatine, the colour of hyperoxide of lead is not changed, not even when boiled; the crystals of kreatine deposited in cooling are free from oxide of lead. A solution of hypermanganate of potash, in which kreatine is dissolved, only loses its red colour by long digestion with the aid of heat, without perceptible disengagement of gas. The liquid now contains no kreatine, and gives on evaporation white crystals; while the potash is found partly combined with carbonic acid.

Action of acids on kreatine. The action of strong mineral acids is very remarkable. A solution of kreatine, to which, while cold, hydrochloric acid is added, gives by spontaneous evaporation crystals of unchanged kreatine. But when heated with strong hydrochloric acid, a solution of kreatine no longer yields crystals of that substance. The same result is obtained with sulphuric, phosphoric, and nitric acids. When kreatine is dissolved in one of these acids, and the solution gently evaporated, crystals are obtained, which are very soluble in alcohol, a property not belonging to kreatine. These crystals contain a portion of the acid employed, in a state of combination.

Kreatinine.

There is formed, in this reaction from kreatine, by a transformation of its elements, caused by contact with strong mineral acids, a new body of totally different chemical properties, a true organic alkali, which I shall call *kreatinine*.

Kreatinine.

Formation of kreatinine, by means of hydrochloric acid,

When crystallised kreatine is exposed, in the drying apparatus described by me, to a current of dry hydrochloric acid gas, at the temperature of 212°, the weight of the apparatus at first increases; but by continuing the heat and the current of gas, the original weight is at last very nearly recovered. Although it thus appears as if kreatine under these circumstances could absorb no hydrochloric acid, this conclusion is at once found to be erroneous, because during the whole continuance of the experiment water is seen to pass off, till the weight of the apparatus becomes constant. If anhydrous kreatine be used for this experiment, an increase of weight is found to take place.

The compound formed in these circumstances is neutral hydrochlorate of kreatinine.

In like manner, hydrochlorate of kreatinine is obtained, when kreatine is covered with concentrated hydrochloric acid in a porcelain dish, and the solution evaporated in the water-bath till all uncombined hydrochloric acid is dissipated.

or by means of sulphuric acid.

When kreatine is mixed with diluted sulphuric acid (for 1 part of kreatine, 1 part of an acid, composed of 27 parts oil of vitriol, and 73 parts water), the solution being evaporated to dryness, and heated till all moisture is expelled, neutral sulphate of kreatinine is left.

From the hydrochlorate or the sulphate, prepared in either of the above ways, kreatinine may be easily obtained.

Separation of kreatinine from the sulphate,

When carbonate of baryta is added to a boiling aqueous solution of the sulphate of kreatinine, till no more effervescence ensues, and the liquid has an alkaline reaction, sulphate of baryta is deposited, and pure kreatinine remains in solution.

and from the hydrochlorate.

From the hydrochlorate the base is obtained, when the aqueous solution of the salt is boiled with hydrated oxide of lead. The hydrochlorate is dissolved in from 24 to 30 parts of water, the solution heated to boiling in a porcelain vessel, and hydrated oxide of lead suspended in water is added in small portions. At first chloride of lead is formed, and the liquid retains its acid reaction; but when more oxide of lead is added, it becomes neutral, or slightly alkaline. If now there be added to the mixture a quantity of oxide of lead three times as great as that already employed, and the whole is kept boiling for some time, a point is at last reached, at which the liquid, no matter how much diluted, seems to be converted into a thick, light, yellow pasty mass. The decomposition is then complete; the liquid is filtered and the residue carefully washed. Should a trace of oxide of lead be dissolved or suspended in the filtered liquid, it is easily removed by means of a little animal charcoal. This process depends on the conversion of the chloride of lead into a basic compound with oxide of lead, which is as insoluble in water as chloride of silver.

Purification of kreatinine.

The solution of kreatinine thus obtained is entirely free from chlorine, and yields, as does also the solution prepared from the sulphate by baryta, on evaporation, perfectly formed crystals of kreatinine.

As, in both methods, all the impurities contained in the carbonate of baryta, or in the oxide of lead, which may contain acetic acid or potash, are left in the solution of kreatinine, it is necessary to bestow particular attention on the perfect purification of the carbonate of baryta or hydrated oxide of lead, which are to be used for this purpose.

Description of the crystals.

The crystals of kreatinine belong to the monoklinometric system, and are formed by the prism ∞ P, the basic terminal face o P, and klinodiagonal terminal face ∞ P ∞. The orthodiagonal is less than the klinodiagonal. The angle o P : ∞ P ∞, that is, the angle of inclination of the principal axis on the klinodiagonal, was found to be = 69° 24′; the angle under which the lateral faces ∞ P meet in the orthodiagonal section, = 98° 20′, and in accordance with this, the angle which ∞ P ∞ forms with ∞ P, = 130° 50′.*

Kreatinine is much more soluble in cold water than kreatine. 1,000 parts of water dissolve 87 parts of kreatinine, or 1 part dissolves in 11·5 parts of water at 60°. In hot water it is much more soluble.

The aqueous solution restores the blue of reddened litmus paper, and a crystal, laid on moist turmeric paper, causes a brown stain at the point of contact.

Kreatinine dissolves in boiling alcohol, and crystallises on cooling. 1,000 parts of alcohol at 60° dissolve 9·8 parts of kreatinine.

Kreatinine is analogous to ammonia.

In its chemical character, kreatinine is quite analogous to ammonia.

Its action on nitrate of silver,

A moderately concentrated solution of nitrate of silver, when kreatinine is added to it, instantly forms a mass of small white needles, which are very soluble in hot water, and crystallise from it unchanged on cooling. They are a basic compound of kreatinine and nitrate of silver.

on corrosive sublimate,

In a solution of corrosive sublimate, kreatinine causes at once a white curdy precipitate, which, in a few minutes, changes to a mass of slender transparent colourless needles.

on chloride of zinc,

In a neutral aqueous solution of chloride of zinc,

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* The crystallometric measurements given in this work have been made by Dr. Kopp.

kreatinine causes instantly a precipitate formed of crystalline grains, appearing under the microscope as round masses, formed of very small needles concentrically grouped.

on salts of ammonia, and on salts of copper,

Kreatinine expels ammonia from ammoniacal salts, and forms with salts of oxide of copper crystallisable double salts of a fine blue colour.

on bichloride of platinum.

Bichloride of platinum, when hydrochlorate of kreatinine is added to it, causes no precipitate if the solution is diluted; but on evaporation in a gentle heat, there are formed deep yellow transparent crystals of considerable size, very soluble in water, less so in alcohol.

A solution of kreatinine to which bichloride of platinum and hydrochloric acid have been added, yields, when evaporated, the same compound, which is a double salt analogous to the double chloride of platinum and ammonium.

The composition of kreatinine deduced from its formation.

The composition of kreatinine is easily deduced from the action of hydrochloric acid gas on kreatine. 0·5775 gm. of kreatine in crystals increased in weight when exposed to a current of that gas, at 202° by only 0·002 gm. The residue, dissolved in water, and precipitated by nitrate of silver, gave 0·5605 gm. chloride of silver, corresponding to 24·68 per cent. of hydrochloric acid.

The fact that the weight is not altered in this experiment, implies that for 24·68 parts of hydrochloric acid absorbed, an equal or very nearly equal weight of water has been expelled.

Now since crystallised kreatine, when heated alone to 212°, loses 12·08 per cent. of water, it is evident that twice this quantity has been expelled, because otherwise, when 24·68 per cent. of hydrochloric acid had been absorbed, the weight must have increased. Since, moreover, 1 eq. of hydrochloric acid weighs 36·5 ($H=1$) and that weight corresponds to 4 eq. of water, it follows that for 1 eq. of hydrochloric acid absorbed, 4 eqs. of water have been expelled.

It follows further, that anhydrous kreatine must gain in weight when exposed to hydrochloric acid gas, to the amount of 14·05 per cent. In fact, 0·5820 gm. of anhydrous kreatine, under these circumstances, absorb 0·084 gm. of hydrochloric acid, corresponding to 14·46 per cent., a coincidence as close as could be obtained.

Kreatine, in forming kreatinine, loses 4 eqs. of water.

The conversion of kreatine into kreatinine, by the action of mineral acids, depends, therefore, on the separation of 4 eqs. of water. If we subtract these from the formula of crystallised kreatine, the composition of kreatinine in 100 parts is as follows :—

Formula.

8 eqs. Carbon	=	48	42·48
3 eqs. Nitrogen	=	42	37·17
7 eqs. Hydrogen	=	7	6·19
2 eqs. Oxygen	=	16	14·16
Atomic weight of Kreatinine ...		113	100·00

Analysis of kreatinine.

In accordance with this theoretical result there were obtained by combustion with chromate of lead the following numbers:

0·3418 gm. of kreatinine yielded 0·5332 gm. carbonic acid, and 0·1965 gm. water.

The same substance yielded, when burned, a gaseous mixture, in which, for 434 volumes of nitrogen gas, there were found 1,132 vol. of carbonic acid.*

According to this analysis, kreatinine contains

Carbon	42·54
Nitrogen	37·20
Hydrogen	6·38
Oxygen	13·88
	100·00

Kreatinine and caffeine.

If we compare with the formula of kreatinine that of caffeine (théine), it appears, that kreatinine contains the elements of 1 atom of caffeine + 1 atom amide. Caffeine is

$C_8 N_2 H_5 O_2$: add to this
1 at : Amide $N H_2$

The sum is $C_8 N_3 H_7 O_2$ = 1 at : Kreatinine.

	N.		$C O_2$
* The 2nd tube yielded	75	for	187
3rd „	77	„	197
4th „	79	„	207
5th „	48	„	126
6th „	70	„	200
7th „	85	„	215
N : $C O_2$ = 3 : 8	434	„	1132

Kreatine and Kreatinine, constituents of human urine.

The compound discovered in urine by Pettenkofer

If we compare the results of the analysis of kreatine and kreatinine with the composition of the substance discovered three years since by Pettenkofer * in human urine, and analysed by him, we perceive at once, that both kreatine and kreatinine must stand in a definite relation to that body. Pettenkofer found that this substance, when burned, yielded a gaseous mixture, containing, for 8 vol. of carbonic acid, 3 vol. of nitrogen. This is the same proportion, as is contained in kreatine and kreatinine; although, on the other hand, he found a variation in the proportion of hydrogen and oxygen. The substance from urine contains 1 eq. of water less than anhydrous kreatine and 1 eq. more than kreatinine.

contains the same proportions of carbon and nitrogen as kreatine and kreatinine.

Although I had no reason to doubt the accuracy of Pettenkofer's analysis, yet I considered it desirable to compare the properties of the substance from urine with those of kreatine and kreatinine.

Pettenkofer's process.

According to Pettenkofer's process for its preparation, fresh human urine is neutralised with carbonate of soda, evaporated till the salts crystallise out, then extracted by alcohol, and mixed with a concentrated solution of chloride of zinc. In this mixture, there are deposited, after some hours or days, small granular hard crystals, frequently in crusts, which contain chloride of zinc and a crystal-

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* Annalen der Chemie und Pharmacie, vol. lii. p. 97.

lisable organic substance. When these crystals are dissolved in hot water, the zinc separated by means of baryta, the filtered liquid evaporated, the residue acted on by alcohol, the alcoholic solution deprived of baryta by sulphuric acid, and the liquid, which now contains hydrochloric acid, sulphuric acid, and the organic compound, boiled with oxide of lead, the sulphuric and hydrochloric acids are thus separated, and the organic compound remains dissolved in alcohol, and gives on evaporation a crystalline white mass, which instantly reproduces the original crystalline precipitate when its solution is mixed with chloride of zinc.

Simpler process proposed by the author.

According to my experiments, this substance may be obtained from urine by a simpler process. The urine is neutralised by milk of lime, and then solution of chloride of calcium is added as long as it causes a precipitate of phosphate of lime. The liquid is then filtered and evaporated till the salts crystallise out on cooling. The mother liquor is separated, without the use of alcohol, from the salts, and mixed with a syrupy solution of neutral chloride of zinc, in the proportion of about ½ ounce to 1 lb. of the extract.

After three or four days the greater part of the zinc-compound of Pettenkofer is found to have crystallised in rounded yellow grains. The deposit is well washed with cold water, then dissolved in boiling water, and hydrated oxide of lead added to the solution, till it acquires a strong alkaline reaction. By this means the zinc and hydrochloric acid are separated in an insoluble form, while the substance, formerly combined with them, remains in solution. This is now acted on with blood-charcoal, which removes a yellow colouring matter and a trace of oxide of lead, and the filtered liquid is evaporated to dryness.

Pettenkofer's substance is a mixture of kreatinine with a little kreatine.

By the process of Pettenkofer, as well as by that just described, there was obtained a white crystalline substance, having, in each case, the same characters. But a closer investigation immediately showed that this substance was a mixture of two compounds of different properties, which may easily be separated by means of alcohol, one of them being easily soluble, the other very sparingly soluble, in hot alcohol. When a portion of the mixed substance is boiled with 8 or 10 times its weight of alcohol, either a part remains undissolved, or the solution is complete, but deposits crystals on cooling. These crystals are found to be identical with the undissolved residue. When they are separated from the mother liquor, and the latter evaporated, a new crystallisation, of different form and properties, is obtained. The body which crystallises first, or remains in the undissolved residue, contains water of crystallisation and has no action on vegetable colours; the more soluble has in its aqueous solution a strong alkaline reaction, its crystals do not effloresce when heated, and the analysis of these two compounds showed, as the external form and chemical characters indicated, Analysis of the compounds from urine.

that the one which first crystallised was kreatine, the other kreatinine. The kreatine thus prepared from urine yielded, when burned with oxide of copper, a gaseous mixture containing, for 3 vols. of nitrogen, 8 vols. of carbonic acid.*

0·6085 gm. lost at 212°, 0·0775 gm. of water, = 12·77 per cent.

0·3686 gm. yielded 0·500 gm. of carbonic acid and 0·2348 gm. of water.

That ingredient of Pettenkofer's substance which was most soluble in alcohol (kreatinine) gave, when burned, a gaseous mixture in which nitrogen and carbonic acid were in the proportion of 280 N to 740 CO_2, or of 3 vols. nitrogen to 8 vols. carbonic acid.† Further, 0·3767 gm. of the same body yielded 0·589 gm. carbonic acid and 0·2112 gm. water.

		N.		CO_2.
* The 2nd	tube yielded	72	for	190
3rd	,,	78	,,	205
4th	,,	74	,,	198
5th	,,	55	,,	202
6th	,,	86	,,	177
		365	,,	972

		N.		CO_2.
† The 2nd	tube yielded	52	for	142
3rd	,,	71	,,	189
4th	,,	69	,,	183
5th	,,	88	,,	226
		280	,,	740

Composition of the substances from urine.

The composition of these two substances in 100 parts is therefore,

	Kreatine from Urine (anhydrous).	Kreatinine from Urine.
Carbon	36·90	42·64
Nitrogen	32·61	37·41
Hydrogen	7·07	6·23
Oxygen	23·42	13·72
	100·00	100·00

They are identical with kreatine and kreatinine.

If we compare these numbers with those obtained by the analysis of kreatine from flesh, and the analysis of the kreatinine prepared from it, it is obvious that they are respectively identical, and indeed no difference can be detected in the physical and chemical characters of the two substances from urine and those from flesh.

It has been stated, that the two substances, which served for the preceding analysis, were obtained from fresh urine; but it seemed to me to be interesting, to ascertain the influence which the putrefaction of the urine has on these substances.

In the putrefaction of urine, the kreatine alone disappears.

When putrid urine, in which, of course, all the urea has been converted into carbonate of ammonia, is boiled with milk of lime till ammonia is no longer disengaged, then filtered, evaporated to a thin syrup, and in this state mixed with chloride of zinc, there separates in the course of a few days a considerable quantity of a yellow granular compound, which contains chlorine and zinc, and under the microscope cannot be distinguished from the compound formed by chloride of zinc in fresh urine. When dissolved in boiling water, and deprived of chloride of zinc and colouring matter by means of hydrated oxide of lead and blood-charcoal, the organic substance contained in it was found to be kreatinine, without a trace of kreatine.

During the putrefaction of urine, therefore, the kreatine is destroyed, while the kreatinine suffers no change.

I consider kreatine to be an accidental and variable ingredient of Pettenkofer's zinc compound; for a warm (not boiling) solution of kreatine is not precipitated by chloride of zinc, and the crystals which are deposited contain neither zinc nor chlorine, but possess all the characters of pure kreatine.

Formation of Pettenkofer's compound.

It is clear that if the fresh urine contain kreatinine in combination with an acid, and free kreatine, *the kreatinine, when it is neutralised by an alkali*, will be set free, and when the liquid is concentrated to $\frac{1}{20}$th of its original volume, the addition of chloride of zinc will precipitate the compound of chloride of zinc with kreatine; but the crystals of this substance will be mixed with those of kreatine, whenever the quantity of kreatine present is more than the liquid can retain in solution when cold.

Urine is an economical source of kreatine and kreatinine.

Although the amount of kreatine and kreatinine, to be obtained from urine, is not considerable, yet I consider the preparation of these substances from urine to be more convenient, and especially more economical, than their extraction from flesh; and by either of the processes just described, they may be obtained in any required quantity by operating on a sufficiently large scale.

Hydrochlorate of kreatinine.

Hydrochlorate of Kreatinine.—This salt, the preparation of which has been already described, dissolves readily in boiling alcohol, and crystallises from it in short, transparent, colourless prisms, very soluble in water; it is obtained by evaporating its aqueous solution in broad transparent scales of an acid reaction. A saturated solution of this salt in boiling alcohol, to which ammonia is added till the acid reaction is destroyed, deposits on cooling small transparent granular crystals of kreatinine.

0·4764 gm. of hydrochlorate of kreatinine yielded 0·5677 gm. carbonic acid and 0·227 water.

Further, 0·542 gm. yielded 0·513 gm. chloride of silver. This gives in 100 parts,

		Calculated.	Found.
8 eqs. Carbon............	48	32·30	32·48
3 eqs. Nitrogen	42	28·11	28·27
8 eqs. Hydrogen.........	8	5·35	5·30
2 eqs. Oxygen	16	10·55	10·54
1 eq. Chlorine	35·4	23·69	23·41
Atomic Weight	149·4	100·00	100·00

Double salt with bichloride of platinum.

Chloride of Platinum with hydrochlorate of kreatinine. — A solution of hydrochlorate of kreatinine gives, on the addition of bichloride of platinum, and gentle evaporation, aurora-red prisms of the double salt. When more rapidly formed, this salt is obtained in yellowish-red transparent grains.

0·6086 gm. of this salt made with kreatine prepared from flesh, left after ignition, 0·1858 gm. platinum.

0·8608 gm. of the same salt, prepared with Pettenkofer's compound, derived from urine, left 0·2665 gm. platinum.

Hence this double salt consists of—

	Calculated.	Found.	
Kreatinine and Hydrochloric acid...	69·05	69·47	69·05
Platinum	30·95	30·53	30·95
	100·00	100·00	100·00

Sulphate of kreatinine.

Sulphate of Kreatinine.—A boiling saturated solution of kreatinine, to which diluted sulphuric acid is added, till a strong acid reaction appears, gives on evaporation a white saline mass, easily dissolved by hot alcohol. While cooling, the solution becomes milky, and deposits (on becoming clear) transparent, concentrically-grouped, four-sided tables of neutral sulphate of kreatinine, the crystals of which salt continue transparent when heated to 212°.

0·439 gm. of sulphate of kreatinine yielded 0·315 gm. of sulphate of baryta.

0·5655 gm. of the same salt gave, when burned, 0·6085 gm. of carbonic acid, and 0·2563 gm. of water.

Hence this salt consists of—

			Calculated.	Found.
1 eq. Sulphuric acid		40	24·69	24·65
1 eq. Kreatinine ...	8 eq. Carbon......	48	29·63	29·33
	3 eq. Nitrogen ...	42	25·92	25·44
	8 eq. Hydrogen...	8	4·94	5·03
	3 eq. Oxygen ...	24	14·82	15·55
1 eq. Sulphate of Kreatinine =		162	100·00	100·00

Sarcosine.

Action of boiling barytic water on kreatine.

Sarcosine.

When, to a boiling saturated solution of kreatine, we add ten times the weight of the kreatine of crystallised hydrate of baryta, the solution continues clear at first, but by continued boiling it becomes turbid, and deposits a white crystalline powder, adhering to the sides of the vessel, which increases as long as the disengagement of ammonia continues. If the boiling be continued, baryta and water being added from time to time, until no further escape of ammonia is perceptible, there is obtained by filtration a transparent colourless liquid, which contains caustic baryta along with a new organic base, to which I have given the name of *Sarcosine.* The white powder remaining on the filter contains no organic matter, and is pure carbonate of baryta.

Its purification.

By passing a current of carbonic acid gas through the liquid, and subsequently boiling, the baryta is separated from the new base, which remains dissolved ; and the solution, when evaporated, gives a syrup, which on standing consolidates into a mass of broad, colourless, transparent plates. For the preparation of pure sarcosine, it is important to use perfectly pure baryta, previously tested for, and if necessary deprived of, traces of potash, lime, chlorine or nitric acid; because all such impurities accumulate in the sarcosine, from which they cannot easily be removed.

To obtain pure sarcosine, it is advisable to convert it, as prepared by the process just described, into sulphate. For this purpose, diluted sulphuric acid is added to the base obtained by the evaporation of the filtered liquid, till it acquires a strong acid reaction. The acid solution is evaporated in the water-bath, and to the syrupy residue alcohol is added, and well mixed with it by means of a glass rod. The syrupy sulphate is thus converted into a white crystalline powder, which is well washed with cold alcohol, then dissolved in water, and the solution digested with pure carbonate of baryta in a warm place, till no further effervescence ensues, and the acid reaction has disappeared. The liquid now contains the pure base dissolved; it is filtered from the sulphate and carbonate of baryta, evaporated in the water-bath to a syrup, and in this state set aside. The sarcosine crystallises in from 24 to 36 hours.

Crystals of sarcosine.

The crystals of sarcosine are right rhombic prisms; acuminated on the ends by surfaces set perpendicular on the obtuser angles of the prism, that is, the combination $\infty p : \bar{P} \infty$. Only the faces

∞ P had lustre enough to admit of approximative measurement; the angles of the prism were found = 103° and 77. Single planes of P and o P occur rarely, and then doubtfully indicated. The crystals are colourless, perfectly transparent, and of considerable size. They are extremely soluble in water, very sparingly soluble in alcohol, and insoluble in ether. When dried at 212°, they retain their original aspect; at a somewhat higher temperature they melt, and sublime without residue. When some crystals of sarcosine are exposed, between two watch-glasses, for a long time to a heat of 212°, the upper glass is covered with a network of crystals of sublimed sarcosine.

Its properties.

Analysis of sarcosine.

The analysis of sarcosine gave the following results. When burned with the oxide of copper, it gave a gaseous mixture, containing 1 vol. of nitrogen for 6 vols. of carbonic acid.* It therefore contains, for 6 eqs. of carbon, 1 eq. of nitrogen.

0·3843 gm. of sarcosine yielded, further, 0·574 gm. of carbonic acid, and 0·2735 gm. of water.

0·3666 gm. yielded 0·550 gm. of carbonic acid and 0·2578 gm. of water.

	N.	CO_2.
* The 2nd tube yielded	42	233
3rd ,,	38	241
4th ,,	40	230
5th ,,	40	243
6th ,,	43	252
	203	1,199

This gives for 100 parts—

Formula of sarcosine.

		Calculated.	Found.	
6 eq. Carbon......	36	40·45	40·73	40·90
1 eq. Nitrogen ...	14	15·73	15·84	15·90
7 eq. Hydrogen...	7	7·86	7·90	7·82
4 eq. Oxygen ...	32	35·96	35·53	35·38
1 eq. Sarcosine...	89	100·00	100·00	100·00

Properties of sarcosine.

The aqueous solution of sarcosine has no action on vegetable colours; it has a sweetish, sharp, somewhat metallic taste; in diluted solutions of nitrate of silver and corrosive sublimate it causes no change. But if a crystal of sarcosine be placed in a cold saturated solution of corrosive sublimate, it is instantly dissolved, and in a short time there are seen to be formed a number of slender transparent needles of a double salt, which, if the quantity of sarcosine is not too small, fill the whole liquid, converting it into a semi-solid mass. A solution of acetate of copper acquires, by the addition of sarcosine, the same deep blue colour as is caused by ammonia, and by gentle evaporation there are obtained thin scales of the same colour.

Hydrochlorate of sarcosine.

When evaporated along with hydrochloric acid, sarcosine yields a white saline mass, which dissolves in hot alcohol, and is deposited on cooling in small transparent grains and needles.

Double salt with bichloride of platinum.

A solution of hydrochlorate of sarcosine, mixed with excess of bichloride of platinum, gives no precipitate; but by spontaneous evaporation it soon forms flattened octohedrons of a honey-yellow colour, which often exhibit faces half an inch broad, lying on each other in the manner of the steps of stairs. By means of a mixture of alcohol and ether, the superfluous bichloride of platinum is easily removed, and the crystals may thus be obtained quite pure.

Analysis of the double salt.

The double chloride of platinum and sarcosine, dried in the air, loses, when further heated to 212°, 6·7 per cent. of water.

0·4544 gm. of the anhydrous salt yielded on ignition 0·1527 gm. of platinum.

If this salt have a composition analogous to that of the double chloride of platinum and ammonium, it would contain—

Its formula.

			In 100 Parts.	
			Theory.	Experiment.
1 eq. Sarcosine	89	196·2	66·85	66·40
1 eq. Hydrochloric acid	36·4			
2 eqs. Chlorine	70·8			
1 eq. Platinum	,,	98·7	33·45	33·60
1 eq. of the anhydrous double salt		294·9	100·00	100·00

The loss of weight at 212° indicates that the crystallised salt contains 2 eqs. of water = 5·7 per cent.

Sulphate of sarcosine.

Sulphate of Sarcosine.—The preparation of this salt has been already described (p. 69). When the residue, well washed with cold alcohol, is boiled with from 10 to 12 times its weight of alcohol, it dissolves, with the exception of a trace of sulphate of baryta; and this solution deposits on cooling transparent colourless four-sided tables of high lustre, which can hardly be distinguished by their aspect from chlorate of potash. They are sparingly soluble in cold alcohol, but very soluble in water, and crystallise from their aqueous solution in large feathery plates. Both the aqueous and alcoholic solutions have a strong acid reaction, so that it is difficult to tell when the washing of them, to remove uncombined acid, is complete. On this account the following analyses of this salt have given a slight excess of sulphuric acid.

Analysis of the sulphate.

0·6928 gm. of sulphate of sarcosine lost, at 212°, 0·049 gm. of water = 6·54 p. c.; and yielded 0·5470 gm. of sulphate of baryta = 29·25 p. c. of sulphuric acid in the anhydrous salt.

0·5899 gm. of sulphate of sarcosine lost, at 212°, 0·0385 gm. of water = 7·07 p. c.; and gave 0·4870 gm. of sulphate of baryta, = 30·36 p. c. of sulphuric acid in the anhydrous salt.

I. 0·3745 gm. of this last portion of sulphate of sarcosine (= 0·2608 gm. after deducting the sulphuric acid) gave 0·3475 gm. of carbonic acid.

II. 0·3388 gm. of the same salt (= 0·2389 gm. after deducting the acid) gave 0·3087 gm. of carbonic acid, and 0·1735 gm. of water.

III. 0·2674 gm. of sulphate of sarcosine (= 0·1865 gm. after deducting the acid) gave 0·2475 gm. of carbonic acid, and 0·138 gm. of water.

If sulphate of sarcosine be analogous in composition to the sulphates of other organic bases, the anhydrous salt contains 1 eq. of sarcosine combined with 1 eq. of hydrated sulphuric acid, and therefore, in calculating the analyses, if we deduct the weight of anhydrous sulphuric acid present, we must obtain in the remainder a formula which includes the elements of sarcosine + 1 eq. of water.

Formula of sarcosine in the sulphate.

The formula $C_6 N H_7 O_4 + H O$ would yield in 100 parts—

		Theory.	Experiment.		
6 eqs. Carbon ...	36	36·73	36·34	35·69	36·28
1 eq. Nitrogen...	14				
8 eqs. Hydrogen	8	8·16	7·90*	8·16	8·25
5 eqs. Oxygen ...	40				
	98				

The loss sustained by the crystallised salt at 212° indicates the presence of 1 eq. of water of crystallisation = 6·1 per cent.

The Sulphate of Sarcosine, when heated to 212°, consists of—

Formula of the sulphate.

		Calculated.	Found.	
1 eq. Sulphuric acid	40	28·98	29·25	30·36
1 eq. Water	9	71·02	70·75	69·64
1 eq. Sarcosine	89			
1 eq. Sulphate of Sarcosine	138	100·00	100·00	100·00

I regret much that want of material prevented me from multiplying experiments with this inter-

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* The hydrogen in this analysis fell below the truth, which arose from the circumstance, that the salt was decomposed by mixture with chromate of lead, and the water of the sulphuric acid being set free, a portion of it was lost in the process of exhausting the tube previous to the combustion.

esting base; but I believe that no doubt can be entertained as to its composition and its atomic weight.

Formation of sarcosine explained.

The formula above given for sarcosine explains its production from kreatine in a satisfactory manner.

If from the elements of crystallised kreatine we subtract those of sarcosine, there remains a formula exactly identical with that of urea.

Kreatine contains the elements of sarcosine and of urea.

From 1 eq. Kreatine	=	$C_8 N_3 H_{11} O_6$
Deduct 1 eq. Sarcosine	=	$C_6 N H_7 O_4$
There remains 1 eq. Urea	=	$C_2 N_2 H_4 O_2$

It is consequently obvious that, in the decomposition of kreatine by baryta, carbonic acid and ammonia are secondary products derived from the decomposition of urea. I have ascertained that a solution of urea in barytic water is resolved by long boiling into carbonate of baryta and ammonia with the same appearances as those above described; and I have also ascertained that urea is present in the liquid when kreatine is boiled with baryta, if examined before the whole of the kreatine is decomposed. If the operation be arrested when the disengagement of ammonia is strongest, the free baryta precipitated by carbonic acid, the liquid filtered and evaporated to dryness, and nitric acid added to the residue, there is obtained a crystalline mass, which when dried in blotting paper and treated with alcohol, yields to that solvent nitrate

Urea is formed in the process.

of urea. If the alcoholic solution be heated with oxide of lead, nitrate of lead is precipitated, and the liquid gives on evaporation colourless prisms, the concentrated aqueous solution of which forms with oxalic acid a crystalline precipitate. These prisms, when heated, melt easily, give off ammonia, and leave a white residue, which, when further heated, is dissipated in the form of the vapour of hydrated cyanic acid.

Sarcosine is isomeric with lactamide and with urethane.

According to the formula established by the preceding analyses for sarcosine, it contains the same elements, and in the same relative proportions, as the *lactamide* of Pelouze and the *urethane* of Dumas. But the insolubility of sarcosine in ether and alcohol sufficiently distinguishes it from these two compounds.

Sarcosine and urea not the only products.

Sarcosine and urea are not, however, the only products of the decomposition of kreatine by baryta. If water be added to the alcohol from which the sulphate of sarcosine has been crystallised, and the liquid neutralised by carbonate of baryta be filtered and evaporated to the consistence of a thin syrup, there are deposited, long before the point is reached at which sarcosine would crystallise, long colourless prisms or scales, of a feeble acid reaction, which at first for this reason I took for an acid. But they are fusible and volatile, without leaving a residue of baryta; they are very soluble in water and alcohol, and also in 30 parts of ether; the aqueous solution causes no precipitate in nitrate of

Another substance occurs;

silver, corrosive sublimate, acetate of lead, or in salts of lime and baryta. Unfortunately I did not obtain a quantity sufficient for an analysis of this substance, so as to decide whether it agrees in composition with urethane, which it much resembles.

possibly urethane.

Inosinic Acid.

When the liquid from flesh, treated as formerly described, has entirely deposited the crystals of kreatine, and is somewhat further concentrated by evaporation, if alcohol be added to it in small quantities till the whole becomes milky, it deposits, when allowed to rest for some days, yellowish or white granular, foliated or acicular crystals, which may be separated from the viscid mother liquor, although slowly, by filtration, and may be washed with alcohol.

These crystals are a mixture of many different substances, among which kreatine is invariably found. If the whole of the phosphoric acid has not previously been removed from the original solution of flesh, this deposit contains phosphate of magnesia; but the chief ingredient is the potash or baryta salt of a new acid, to which I shall give the name of Inosinic acid.

Inosinic acid.

If the quantity of baryta added has been exactly sufficient to precipitate the whole of the phosphoric acid, the crystals contain inosinate of potash; and finally, if the baryta has been added in excess, they consist of inosinate of baryta, or a mixture of these two salts.

Its purification.

To purify the acid, the deposit is dissolved in hot (not boiling) water, and chloride of barium is added to the solution. On cooling, crystals of inosinate of baryta are deposited, which, by a recrystallisation, are rendered perfectly pure.

Inosinic acid is easily prepared from the inosinate of baryta, by the cautious addition of sulphuric acid to separate the baryta; or from the inosinate of copper by the action of sulphuretted hydrogen. The solution of the latter salt, after being decomposed by sulphuretted hydrogen, is generally brown and turbid, from suspended sulphuret of copper, but it is rendered colourless by a little blood-charcoal and filtration.

Its properties.

Prepared by either process, the solution of the inosinic acid has a strong acid reaction, and possesses an agreeable taste of the juice of meat. When evaporated, it yields a syrup, which, after weeks, exhibits no signs of crystallisation. If this syrup be mixed with alcohol, the thick viscid fluid is changed into a hard, firm, pulverulent mass, of which alcohol dissolves only traces. From a concentrated aqueous solution the acid is precipitated in white amorphous flocculi. It is insoluble in ether.

The quantity of this acid at my disposal was not sufficient for an analysis of it; but the analysis of the baryta salt is sufficient to determine the composition of the acid.

Analysis of inosinate of baryta.

0·312 gm. of inosinate of baryta, dried at 212°, yielded, when ignited with a mixture of soda and lime, 0·565 gm. of the double chloride of platinum and ammonium = 11·370 p. c. of nitrogen.

The combustion of the inosinate of copper yielded a gaseous mixture, containing for 137 vols. of nitrogen 673 volumes of carbonic acid. This indicates that inosinic acid contains, for 1 eq. of nitrogen, 5 eqs. of carbon.*

0·4493 gm. of dried inosinate of baryta yielded 0·2043 gm. of sulphate of baryta = 30·07 p. c. of baryta.

0·5430 gm. of dried inosinate of baryta yielded 0·2546 gm. of sulphate of baryta = 30·75 p. c. of baryta.

0·4248 gm. of the same salt, burned with chromate of lead, yielded 0·381 gm. of carbonic acid, and 0·101 gm. of water.

0·4178 gm., burned with chromate of lead, yielded 0·380 gm. of carbonic acid, and 0·0975 gm. of water.

	N.	CO_2.
* The 2nd tube yielded	49	235
3rd ,,	45	245
4th ,,	42·5	193·5
	136·5	673·5

$N : CO_2 = 1 : 5$.

Hence, the anhydrous inosinate of baryta contains—

Formula of the anhydrous salt.

		Calculated.	Found.	
10 eqs. Carbon	60	23·96	24·46	24·80
2 eqs. Nitrogen	28	11·18	11·37	11·37
6 eqs. Hydrogen	6	2·40	2·64	2·59
10 eqs. Oxygen	80	31·95	31·46	30·79
1 eq. Baryta	76·4	30·51	30·07	30·75
1 eq. Inosinate of Baryta	250·4	100·00	100·00	100·00

Formula of the anhydrous acid,

After deducting the baryta, the anhydrous acid combined with it contains

10 eqs. of Carbon,
2 eqs. of Nitrogen,
6 eqs. of Hydrogen,
10 eqs. of Oxygen ;

and of the hydrated acid.

And if we suppose the baryta replaced by its equivalent of water, the formula of inosinic acid will be $C_{10} N_2 H_7 O_{11} = C_{10} N_2 H_6 O_{10} + H O$.

Inosinates.

Inosinates.—Free inosinic acid does not precipitate lime-water or barytic-water, but when these mixtures are left to evaporate in the air, there are formed transparent pearly scales of the inosinates of lime and baryta. The free acid, as well as its soluble salts, cause a precipitate in acetate of copper; the inosinate of copper appears as a fine greenish-blue precipitate, which does not dissolve even in boiling water, and is not blackened by it. Salts of silver are precipitated white by inosinates; the precipitate is gelatinous, of the aspect of hydrate of alumina, soluble in nitric acid and ammonia. In the salts of lead inosinic acid causes a white precipitate. The salts of inosinic acid with the alkalies are decomposed when heated on the platinum spatula, and give out a strong and agreeable smell of roast meat.

Inosinate of potash.

Inosinate of Potash.—This salt is obtained from the baryta salt by cautious precipitation of the baryta by carbonate of potash, and also directly from the juice of flesh (see p. 77). It is very soluble in water, and crystallises in long slender four-sided prisms. It is insoluble in alcohol, and is precipitated by it, even from diluted aqueous solutions, as a granular powder. The addition of alcohol to a concentrated solution of inosinate of potash causes it to become semi-solid, from the deposition of fine pearly scales. The following determination of the amount of potash was made with a specimen of the salt prepared directly from the juice of flesh after the separation of kreatine. The salt was dissolved in water, precipitated by nitrate of silver, the precipitate well washed, and the potash in the filtered liquor determined in the form of nitrate.

0·4484 gm. of inosinate of potash lost, when heated to 212°, 0·0987 gm. of water = 22·02 p. c.

0·3495 gm. of the anhydrous salt yielded 0·156 gm. of nitrate of potash.

The calculated composition of the anhydrous salt in 100 parts is—

			Found.
1 eq. Inosinic acid	174	78·7	79·27
1 eq. Potash	47·2	21·3	20·73
1 eq. Inosinate of potash[*]	221·2	100·0	100·00

Formula of the anhydrous salt.

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[*] C

The loss of weight at 212° indicates the presence of 7 eqs. of water of crystallisation = 22·5 per cent.

Inosinate of soda.

Inosinate of Soda.—This salt crystallises in slender needles, of silky lustre, and is extremely soluble in water, but insoluble in alcohol.

Inosinate of baryta.

Inosinate of Baryta.—This salt dissolves sparingly in cold, more easily in hot water, and is insoluble in alcohol. 1000 parts of water at 60° dissolve 2·5 parts of inosinate of baryta. When acted on by hot water, it exhibits a peculiarity similar to what is observed in phosphosinate of baryta. If a solution, saturated at from 140° to 158°, is heated to boiling, a part of the salt is deposited in the form of a resinous mass; again, while water at 158° dissolves a certain amount of the salt, the same quantity of boiling water always leaves a part undissolved, and this residue, by long boiling, undergoes a change, by which it loses its solubility even in water at the lower temperature above mentioned.

The crystals of inosinate of baryta are longish four-sided scales of pearly lustre, which, when dry, have the aspect of polished silver. At 212° the crystals lose water, becoming dull and opaque; in dry air they readily effloresce.

0·555 gm. of the crystallised salt lost, when heated to 212°, 0·1059 gm. of water.

1·060 gm. lost, at 212°, 0·2020 gm. of water.

This gives for 100 parts of salt 19·07 of water. If the inosinate of baryta, like the inosinate of potash, contained 7 eqs. of water, it would have lost 20 p. c. of water.

Inosinate of Copper.—This salt, when dried, forms a light blue amorphous powder. It is, in the common sense of the term, insoluble in water, which only dissolves so much of it, that ferrocyanide of potassium causes a faint redness, such as salts of copper exhibit when diluted with 500,000 parts of water. It is insoluble in acetic acid, easily soluble with a blue colour in ammonia.

Inosinate of copper.

Inosinate of Silver.—The gelatinous precipitate, formed by soluble inosinates in salts of silver, is somewhat soluble in pure water, but less so in water containing nitrate of silver. It is not blackened by light, or only to a very trifling extent.

Inosinate of silver.

The inosinate of silver obtained in the analysis of the potash salt (see p. 81), was decomposed by sulphuretted hydrogen, and the sulphuret of silver thus obtained converted into chloride of silver.

0·3495 gm. of the anhydrous inosinate of potash yielded, in this way, 0·216 gm. of chloride of silver, corresponding to 49·99 parts of oxide of silver, from 100 parts of the potash salt.

If the inosinate of silver be proportional in composition to the inosinate of potash, 100 parts of the latter salt ought to yield 51·02 parts of oxide of silver. The experiment gave, as we have seen, 50 parts of oxide of silver.

This difference is considerable; but when so many operations must be performed with one and the same portion of substance, errors of this kind are unavoidable. I am quite aware how imperfect is the investigation of inosinic acid, and of its salts, which I have been able to make; but flesh contains only a very small quantity of this substance; and of that which I obtained, a great part was necessarily consumed in ascertaining its nature and properties.

Inosinic acid is probably a coupled acid.

Inosinic acid appears, from its composition, to belong to the coupled acids. Considered as hydrate, it contains the elements of acetic acid, oxalic acid, and urea :—

1 eq. anhydrous Acetic acid	$C_4 \; H_3 \; O_3$
2 eqs. anhydrous Oxalic acid	$C_4 \; O_6$
1 eq. Urea	$C_2 \; N_2 \; H_4 \; O_2$
1 eq. hydrated Inosinic acid	$C_{10} \; N_2 \; H_7 \; O_{11}$

When the acid is heated with hyperoxide of lead, with the addition of diluted sulphuric acid, the oxide loses its brown colour and becomes white, and the filtered liquid, when deprived of the excess of sulphuric acid, deposits on evaporation needle-shaped crystals. When mixed, in the concentrated state, with nitric acid, no precipitate occurs, but there are obtained by evaporation small colourless granular crystals, which I could not further examine, on account of the smallness of the quantity of inosinic acid which I was able to devote to this experiment.

Effect of temperature on the

The temperature at which the solution of the juice of flesh is evaporated, has a great influence on the preparation of the salts of inosinic acid. In many instances, when the temperature had never exceeded 212°, I have obtained no trace of inosinate of potash or baryta; while fluid, derived from the flesh of the same animal, yielded tolerably large quantities, when during the evaporation a strong current of air was made to pass over the surface of the liquid, by which means its temperature was kept as low as from 122° to 140°.

preparation of inosinates from the juice of flesh.

Kreatinine, as a Constituent of Muscle.

When the juice of flesh, from which the inosinates have been precipitated by alcohol, is mixed with an additional quantity of alcohol, it separates, after about five times its volume of alcohol have been added, into two layers, of which one, a thick syrupy, of a brownish-yellow colour, amounting to 1-20th of the bulk of the other, falls to the bottom of the vessel. If these liquids are mixed by agitation, they again separate on standing.

Kreatinine exists in the juice of flesh.

In the heavy viscid portion, at a temperature of 23°, there are soon formed a number of transparent colourless four-sided prisms, which are pure chloride of potassium. They melt when heated, without blackening; their aqueous solution precipitated nitrate of silver, and gave, with bichloride of platinum, a yellow precipitate; while the mother liquid, when mixed with alcohol, contained no traces of the double chloride of platinum and sodium.

Its extraction.

If the lighter fluid be poured off from the heavy viscid one, and the latter mixed with its own volume of ordinary ether, it becomes milky, and on standing a new separation takes place.

On the bottom of the vessel there collects an amber-yellow viscid liquid, from which the supernatant lighter ethereal liquid can be easily separated by decantation. The heavier consists almost entirely of lactate of potash ; the lighter contains also a certain quantity of that salt, but the chief ingredient of it is an organic base, which in properties and composition has been found to be identical with kreatinine.

When the ether and alcohol are distilled off from this lighter fluid, and the residue evaporated to the consistence of a thin syrup, it forms, on cooling, a semi-solid mass of slender foliated crystals, which, by the addition of alcohol, may be separated from the mother liquid. When these crystals are washed with a little alcohol, dried, and dissolved in boiling alcohol, the solution deposits, on cooling, crystals possessing the form and properties of kreatine. At 212° they become opaque and dull, and lose twelve per cent. of water. The mother liquid, by gentle evaporation, yields yellowish four-sided tables. By means of a little blood-charcoal and hydrated oxide of lead, they are easily rendered colourless; their aqueous solution is strongly alkaline, and causes white crystalline precipitates in solutions of nitrate of silver, corrosive sublimate, and chloride of zinc. When mixed with hydrochloric acid and bichloride of platinum, yellow crystals are obtained, of the form and properties of the double chloride of platinum and kreatinine.

Of this platinum salt, 3·3728 gm. yielded on ignition 0·1153 gm. of platinum = 30·92 p. c. This is the same per-centage of platinum as in the double chloride of platinum and kreatinine.

A portion of the same salt, burned with oxide of copper, yielded a gaseous mixture, containing for 3 volumes of nitrogen 8 volumes of carbonic acid.*

This is the same proportion as in kreatinine.

0·1513 gm. of the dried crystals of kreatinine, prepared directly from flesh, yielded 0·2316 gm. of carbonic acid, and 0·0865 gm. of water.

Analysis c kreatine from the juice of flesh.

Hence this substance contains, in 100 parts—

	Kreatinine from Flesh.	Kreatinine from Kreatine.
Carbon	41·7	42·54
Nitrogen	,,	,,
Hydrogen	6·23	6·38
Oxygen	,,	

These results leave no doubt as to the nature of this substance, and the occurrence of kreatinine in the organism. The objection, that the kreatinine might have been formed by the action of the free

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	N.	CO_2.
* The 2nd tube yielded	60	156
3rd ,,	66	176
4th ,,	79	211
	205	543

N : C = 3 : 8.

acid in the juice of flesh on the kreatine, during the short heating necessary to coagulate the albumen, is at once destroyed by the occurrence of kreatinine in neutralised urine, and also by the fact that kreatine may be dissolved and boiled for a long time in mineral acids of much greater concentration than the acid of the juice of flesh possesses, without suffering the slightest change.

Simple process for extracting kreatinine from flesh.

Now that the nature of this substance, which I at first took for a peculiar base, different from kreatine, is known, it is no longer necessary to employ the circuitous methods which I was compelled to adopt, in order to prevent all foreign chemical action during its preparation. When the mother liquid which has deposited the inosinates is evaporated to dryness in the water-bath, and boiled with alcohol, all the kreatinine is dissolved, and when chloride of zinc is added to the solution, Pettenkofer's compound is deposited either at once or after some hours, as a crystalline deposit, from which, when acted on by hydrated oxide of lead, pure kreatinine is easily obtained.

Lactic Acid.

Lactic acid is a constituent of flesh.

When the liquid, from which the inosinates have been deposited, is evaporated in the water-bath, and the residue acted on by alcohol, all the lactates are dissolved. If the alcoholic solution be separated from the syrupy viscid liquid which is insoluble in it, and the alcohol distilled off, there is left a yellow syrup which, in the course of 8 or 10 days, forms a soft semi-solid crystalline mass. The crystals which form in it consist of kreatine, and of the potash salt of a nitrogenised acid, differing in properties from inosinic acid; they are contained in a mother liquid, the chief ingredient of which is uncrystallisable lactate of potash.

Preparation

To prepare lactic acid from this mass, it is mixed with its own volume of diluted sulphuric acid (made with 1 vol. of oil of vitriol and 2 vol. of water), or with a solution of oxalic acid of equal strength. Of the latter, so much is added as to produce a crystalline deposit, and, in either case, 3 or 4 times its bulk of alcohol is added to the mixture.

and purification of the lactic acid.

By the addition of alcohol, the sulphate or oxalate of potash is precipitated, while the lactic acid remains in solution. This solution is mixed with ether till no further turbidity is produced, the liquid is filtered from the deposit, the ether and alcohol are distilled off, and the residue is concentrated in the water-bath to the consistence of syrup. This syrup is again acted on by a mixture of alcohol and ether, half its volume of alcohol being first added, and then 5 times its volume of ether, by which means a nearly pure solution of lactic acid in ether is obtained. The ether is then distilled off and the residue mixed with milk of lime, till it acquires a strong alkaline reaction. The liquid is filtered, and the solution of lactate of lime is left in a warm place, where it soon forms a mass of crystals, which are in themselves colourless, but appear yellow from the adhering mother liquor. The mass is diluted with alcohol, and thrown on a filter, where it is washed by cautiously adding cold alcohol so as to displace the mother liquor, till the crystals appear quite white. In order to separate any gypsum that may be present, they are now dissolved in alcohol of 60 per cent., the solution is filtered, treated, if coloured, with blood-charcoal, and evaporated, when it readily yields perfectly pure lactate of lime.

Modification of the process for fish.

From every sort of flesh, except that of fishes, lactate of lime may be obtained by this process; but for fish it is necessary to modify it. The liquid, for example, obtained from the flesh of the pike, is evaporated to a syrup, and mixed with an aqueous solution of tannic acid, which causes a thick yellowish white precipitate, softening like pitch when heated. The filtered liquid is concentrated, and treated as above directed with sulphuric or oxalic acid, and at last there is obtained, in the ethereal solution, a mixture of gallic acid (formed by the oxidation of tannic acid) and lactic acid, from which, when the alcohol is expelled, the gallic acid partly crystallises. Without separating these crystals, the acid mixture is saturated with milk of lime, the solution is filtered from the dark brown (nearly black) residue, treated with blood-charcoal, and concentrated, when after a time it yields snow-white crystals of lactate of lime.

When the lime is precipitated from the solution of the pure lactate by sulphuric acid, the filtered liquid evaporated in the water-bath, and the residue acted on by ether, pure lactic acid is dissolved, and from this any other lactate may be easily prepared.

1·276 gm. of lactate of lime lost, when heated to 212°, 0·323 gm. of water = 25·3 per cent.

1·4735 gm. of lactate of lime lost, when heated to 212°, 0·3805 gm. of water = 25·8 per cent.

Analysis of the lactates prepared from flesh.

Gm.				Gm.		p.c. of lime
0·4900	of lactate of lime	(fowl)	yielded	0·2195	of carbonate of lime	= 25·53
0·4870	,,	(horse)	,,	0·2245	,,	= 25·84
0·5377	,,	(fox)	,,	0·2452	,,	= 25·54
0·1805	,,	(pike)	,,	0·0830	,,	= 25·74
Mean proportion of lime in 100 parts of the salt........................						= 25·65

Lactate of lime.

Hence, lactate of lime contains, in 100 parts—

		Calculated.	Found.			
			I.	II.	III.	IV.
1 eq. Lactic acid.........	81	74·32	74·47	74·19	74·46	74·26
1 eq. Lime	28	25·68	25·53	25·81	25·54	25·74
1 eq. Lactate of lime ...	109	100·00	100·00	100·00	100·00	100·00

Formula of the anhydrous

The crystallised lactate of lime contains—

		Calculated.	Found.	
1 eq. Lactate of lime............	109	75·18	74·7	74·2
4 eqs. Water......................	36	24·82	25·3	25·8
1 eq. crystallised Lactate of lime	145	100·00	100·0	100·0

and of the crystallised salt.

0·274 gm. of anhydrous lactate of lime (ox) yielded by combustion with chromate of lead, 0·3335 gm. of carbonic acid, and 0·1152 gm. of water.

0·6420 gm. of anhydrous lactate of lime (fox) yielded 0·7660 gm. of carbonic acid, and 0·274 gm. of water.

The anhydrous lactate of lime therefore contains—

Composition of lactate of lime;

		Calculated.	Found.	
6 eqs. Carbon	36	33·02	33·11	32·54
5 eqs. Hydrogen	5	4·59	4·66	4·70
5 eqs. Oxygen	40	36·71	36·58	37·11
1 eq. Lime	28	25·68	25·65	25·65
1 eq. anhydrous Lactate of lime	109	100·00	100·00	100·00

of lactate of zinc.

The lactate of zinc, prepared from flesh, was also analysed.

Gm.		Gm.		p.c.
0·499	of lactate of zinc, when heated to 212°, lost	0·068	of water	= 13·6
1·3295	,, ,,	0·1775	,,	= 13·3
	Mean loss			13·45

0·564 gm. of crystallised lactate of zinc left, when ignited, 0·1645 gm. of oxide of zinc = 29·16 per cent.

0·3153 gm. of anhydrous lactate of zinc left, when ignited, 0·1052 gm. of oxide of zinc = 33·31 per cent.

0·5690 gm. of the anhydrous lactate yielded, by combustion, 0·6125 gm. of carbonic acid, and 0·213 gm. of water.

0·2260 gm. of the anhydrous lactate yielded, by combustion, 0·244 gm. of carbonic acid, and 0·0838 gm. of water.

Its formula

Hence, the crystallised lactate of zinc contains*—

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* According to the investigations of Engelhard and Maddrell, lactate of lime, prepared by Frémy's process, contains 5 eqs. (= 29 p. c.) and the lactate of zinc 3 eqs. (= 18 p. c.) of water of crystallisation. It is possible, that this variation in the

in the crystals;

		Calculated.	Found.
1 eq. Lactic acid	81	58·07	57·44
1 eq. Oxide of zinc	40·5	29·03	29·16
2 eqs. Water	18	12·90	13·40
1 eq. crystallised Lactate of zinc	139·5	100·00	100·00

in the anhydrous state.

The ultimate analysis of the anhydrous lactate of zinc gives—

6 eqs. Carbon	36	29·63	29·35	29·44
5 eqs. Hydrogen	5	4·11	4·16	4·12
5 eqs. Oxygen	40	32·93	33·18	33·13
1 eq. Oxide of zinc	40·5	33·33	33·31	33·31
1 eq. anhydrous Lactate of zinc	121·5	100·00	100·00	100·00

The non-azotised acid of flesh is lactic acid.

From the preceding analysis it evidently appears that the non-nitrogenised acid occurring in the animal organism is identical with the acid formed in milk when it becomes sour, and into which sugar of milk, starch, grape sugar, and cane sugar are converted by contact with animal substances in a state of decomposition.*

The inorganic Constituents of the Juices of Flesh.

Inorganic constituents of the juice of flesh.

Chevreul has already directed attention to the very large quantity of inorganic substances contained in the juice of beef. In his experiments they

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amount of water in these two salts depends on this, that the lactates from flesh were crystallised by slow evaporation, and not by cooling.

* From the most recent researches of Engelhard and Maddrell, lactic acid appears to be a bibasic acid. It forms an acid salt with baryta, and its formula must consequently be doubled.

amounted to rather more than a fourth part of the weight of the matters dissolved in the soup when the flesh is boiled with water. Of the saline mass which he obtained by drying up and incinerating the solution, 81 per cent. were found soluble in water, and the insoluble residue of 19 per cent. consisted of 5·77 of phosphate of lime and 13·23 of magnesia.

Alkaline salts preponderate in it.

It is evident that alkaline salts are the preponderating inorganic constituents of the juice of flesh, and that phosphate of lime is in the smallest proportion compared to those salts and to the magnesia.

Importance of the inorganic constituents.

Now, since we may assume with a degree of probability almost amounting to certainty, that, in so perfect a machine as the animal organism, every part has its significance, I have thought it of importance to make some experiments on the nature of the mineral acids and alkaline bases occurring in the juice of flesh, and their mutual relations, experiments which, however imperfect, may still serve as points of departure for future researches.

The organised constituents of the body have been derived from unorganised matters, and return to the unorganised state; and it is especially with the unorganised substances that our researches must begin. If now it can be demonstrated by investigation that certain inorganic constituents occur in the flesh of all animals, and are never absent therefrom, it will follow that they are essential to the function of the muscles, those most complex parts of the organism;

while, on the other hand, a variation in their relative proportions enables us to infer a corresponding variation in some vital action.

The ash of the juice of meat contains only alkaline phosphates and chlorides.

When the juice of flesh (extracted as formerly described, and therefore diluted with water) is evaporated, even without the addition of baryta, it acquires at last, even when the temperature never exceeds 112°, a brown colour, and a taste of roast meat, and leaves when ignited an ash, which may be burned white, although with some difficulty. This ash dissolves almost entirely in water, and in this solution acids occasion no effervescence; the ash, therefore, contains no alkaline carbonates. A more minute examination shows that it consists only of alkaline phosphates and chlorides.

No sulphates are present.

The precipitate formed by baryta in the juice of flesh in many cases dissolves entirely in diluted nitric acid; and in those cases in which a residue of sulphate of baryta is left, its quantity is so trifling that, for example, in the entire flesh of a fowl or of a fox its weight cannot be ascertained. Sulphates or sulphuric acid are therefore not present in the juice of flesh, a fact already ascertained by Berzelius.

The different forms of phosphoric acid.

The soluble salts obtained from the ash of the juice of flesh contain the different modifications of phosphoric acid, which are easily distinguished by their action on nitrate of silver.

It is well known that common or tribasic phosphoric acid forms three different salts with the alkalies; two of these, in their aqueous solution, have an alkaline, the third has an acid, reaction.

Characters of the different forms of tribasic phosphates.

When a salt of phosphoric acid with 3 atoms of fixed base, which is strongly alkaline, is mixed with neutral nitrate of silver, a *yellow* precipitate is formed, the alkaline reaction disappears, and the mixture, after precipitation, if a slight excess of the nitrate of silver be present, is perfectly neutral to test-paper.

The salts of tribasic phosphoric acid with 2 atoms of fixed base have also an alkaline reaction. They give with neutral nitrate of silver the same *yellow* precipitate, and the mixture, after precipitation, is neither alkaline nor neutral, but acid.

When these latter salts are ignited, they are converted into pyrophosphates (bibasic phosphates), which, when dissolved in water, exhibit an alkaline reaction, and give with neutral nitrate of silver a *white* precipitate. After precipitation, the mixture is neutral.

The salts of tribasic phosphoric acid with 1 atom of fixed base have a strong acid reaction. With neutral nitrate of silver they give the *yellow* precipitate formerly mentioned, while the mixture retains its acid reaction.

When ignited, these latter salts pass into metaphosphates (monobasic phosphates), of which the metaphosphate of potash is not soluble in water. Metaphosphate of soda dissolves readily in water, and gives with nitrate of silver a *white* precipitate, which again dissolves in an excess of the precipitant.

Characters of the ashes of the juice of flesh,

If we compare with the characters just described those of the ash of the juice of flesh, we observe the following facts. The ashes of the juice of flesh, in the case of the ox, horse, fox, and roe-deer, give with water a strongly alkaline solution, which is precipitated, first white, then yellow, by neutral nitrate of silver; and the mixture, after complete precipitation, is perfectly neutral. This proves that the ashes contain salts of phosphoric acid, with 2 atoms (pyrophosphates), and with 3 atoms (tribasic phosphates) of fixed alkaline base.

they contain pyrophosphates and tribasic phosphates.

If these ashes are mixed with nitric acid, dried up, and again ignited, by which means the chlorine of the alkaline chlorides is expelled, and the metals added to the phosphates in the form of oxides, the proportion between the white and the yellow precipitate with nitrate of silver is altered, the quantity of the yellow precipitate being increased; but the two colours of the precipitate are constantly observed.

The ashes of the juice of fowl con-

The ashes of the juice of the flesh of fowl give a different result. The aqueous solution precipitates nitrate of silver pure white; the ashes, therefore, contain alkaline pyrophosphates; and when they are acted on by nitric acid and again ignited, the soluble portion still precipitates nitrate of silver only white, although an additional quantity of alkali is thus added to the phosphate originally present.

tain pyrophosphates and metaphosphates.

From this it follows, that the juice of the flesh of fowl must contain a certain though small quantity of alkaline phosphate with 1 atom of fixed base (metaphosphate), since, otherwise, after the action of nitric acid on the ashes, a certain quantity of phosphate with 3 atoms of fixed base (tribasic phosphate) must have been produced, and thereby a yellow precipitate must have been formed, to a corresponding extent, in the nitrate of silver.

Proportion of alkalies to the phosphoric acid.

The whole amount of alkalies, therefore, present in the juice of the flesh of the ox, horse, fox, and roe-deer, is not sufficient to convert the phosphoric acid of the juice entirely into the so-called neutral salt, that is the salt with 3 atoms of fixed base. In the fowl, the whole of the alkali is not even sufficient to convert the phosphoric acid entirely into the salt with 2 atoms of fixed base.

I have mentioned in a preceding part of this memoir, that the juice of flesh, even before all the phosphoric acid has been precipitated by baryta, at a period, therefore, when it can contain no baryta dissolved, acquires an alkaline reaction.

The organic acids in the juice are not sufficient to neutralise the alkalies.

From this it is plain, that the organic acids present in the juice, the lactic and inosinic acids, &c., taken together, are not in sufficient quantity to form neutral salts with the alkalies contained in it, potash and kreatinine; and this necessarily implies that the acid reaction of the juice of flesh is caused by the presence of acid salts of the alkalies with the three acids—phosphoric, lactic, and inosinic acids. Inosinic acid constitutes too small a part of the juice to allow us to ascribe to it a perceptible share in producing the acid quality of that fluid; and this acidity depends, therefore, on the presence of acid alkaline lactate and acid alkaline phosphate (phosphate with one atom of alkali); or, in other words, of neutral alkaline lactate and phosphate, along with free lactic and phosphoric acids.

The acidity of the juice depends on the presence of free lactic and phosphoric acids.

It is obvious, that these two acids are shared between the bases present, and that the amount of free acid present must stand in a definite relation to the quantity of the bases.

Between the two acids, so far as they are uncombined, an equilibrium is established; the quantities of the free acids are proportional to their affinity or power of combination.

Equilibrium between these free acids.

If we suppose the quantity of one of these free acids to be by any means increased in the juice of flesh, that portion of the other, which is free, must in like manner increase; and if, by any means, the amount of the one free acid be diminished, the free portion of the other must diminish in the same proportion, so that a new equilibrium may be established between the free portions of both. If, for example, a portion of phosphoric acid be added to that present in the juice, a part of this must seize on a part of the alkali of the alkaline lactate; thus a new quantity of acid phosphate of the alkali will be formed, and a corresponding amount of lactic acid set free. Exactly in the same way must a corresponding quantity of phosphoric acid be set free, when the amount of lactic acid present is in any way increased.

Now, since the quantity of phosphoric acid in the juice is sufficient to neutralise all the alkali present, while the organic acids are present in smaller proportion and do not suffice to form neutral salts with the alkali, it follows that the removal of lactic acid would give rise to the production of neutral phosphates, and the removal of phosphoric acid would cause the formation of neutral lactates, along with free alkali.

When either the organic acids or the phosphoric acid are removed, the residue is alkaline.

The salt of phosphoric acid, which is formed when all organic acids are removed from the juice of flesh, although neutral in composition, has an alkaline reaction; and when all the phosphoric acid is removed, there are left salts of organic acids, which, from the presence of free alkali, also possess an alkaline reaction.

Explanation of some processes in the organism.

The preceding considerations naturally lead to the explanation of some processes in the animal organism. If the stomach obtain from the blood the same acids, which we have found to exist in the juice of flesh, the blood must possess, during digestion, a stronger alkaline quality than it has in the normal state; and consequently, if the blood is to preserve its normal condition, it must either obtain from the muscles a supply of acid, exactly equal to that which has passed into the stomach, or the excess of alkali must be conveyed to the muscles, or secreted by the kidneys. If the urine of the animal were acid before digestion, it must, on the latter supposition, become, during that process, transiently neutral or alkaline; if it contained a certain quantity of free alkali, that must be increased.

What purpose is served by the lactic acid?

The function of the kidneys, as has long been known, consists in the preservation of an equilibrium in the quality of the contents of the blood; and this includes the removal of products of the change of matter, and of all such substances as affect the normal quality of the blood. In this point of view the solution of the question, "What purposes does lactic acid serve in the organism?" is of peculiar importance. On this point I have made some experiments, which may perhaps assist us in approaching nearer to the solution.

Lactic acid does not occur in healthy urine.

I have, in the first place, repeatedly endeavoured to detect the presence of lactic acid in fresh urine, possessing the usual acid reaction. But I have not been fortunate enough, with the aid of the same process by means of which I succeeded in demonstrating its presence in the juice of flesh, to detect even a trace of lactic acid in the urine of healthy young men. The urine was evaporated in the water-bath to the consistence of syrup, mixed with diluted sulphuric acid, and the acids thus set free taken up by alcohol. The alcoholic solution was evaporated in the water-bath to a thin syrup, to which half its bulk of alcohol and then ether were added, until no more turbidity ensued. If lactic acid were present, it must have been dissolved in this liquid, which evidently contained much hydrochloric acid. The ether was removed by evaporation, the residue diluted with water, and acted on, when cold, with an excess of oxide of silver. All the hydrochloric acid was in this way separated as chloride of silver; had lactic acid been present, the very soluble lactate of silver must have been formed; but no oxide of silver remained in the filtered solution. The addition of milk of lime precipitated no oxide of silver, and the solution thus neutralised gave on evaporation a small quantity of very pure urea, but no lactate of lime.

Putrid urine, treated in the same way, yielded a little acetate of lime in slender needles, but in no instance lactate of lime.

The urine of healthy men, which has an acid reaction, contains, therefore, no lactic acid, and no substance from which lactic acid can be formed during the putrefaction of urine.*

It cannot be detected in the urine when taken internally.

With respect to the presence of lactic acid in alkaline urine, the following experiment is sufficiently decisive. Three persons, among whom were my two assistants, took a quantity of lactate of potash sufficient to have yielded an ounce of

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* The absence of lactic acid in the urine which I examined, does not exclude the opinion, that in certain conditions lactic acid may occur in the urine, as occurs in regard to other constituents of the body, which are not found in the urine of healthy persons, while they may be detected in that fluid in certain pathological states.

lactate of zinc. All the urine for the two subsequent hours was collected. In each case the urine before the experiment had an acid reaction; that which was passed immediately after taking the lactate was strongly alkaline, and the potash was easily detected in it, the quantity of that base present exceeding that in ordinary urine. But it was impossible to detect the lactic acid in this urine; it had entirely disappeared during its passage through the blood.

The lactic acid is consumed in respiration.

From this it plainly appears, that the lactic acid in the organism is employed to support the respiratory process, and the function performed by sugar, starch, and in general all those substances which, in contact with animal matter are convertible into lactic acid, ceases to be an hypothesis. These substances are converted in the blood into lactates, which are destroyed as fast as they are produced, and which only accumulate where the supply of oxygen is less, or where some other attraction is opposed to the agency of that element. When we consider that the urine of graminivorous animals contains a large quantity of free alkali, which is secreted from the blood; that, consequently, in the blood a current of dissolved alkalies is carried through the whole mass of the body, and especially through the substance of the muscles, while the fluid which is in contact with the external part of the blood-vessels and lymphatics (the juice of flesh) retains an acid reaction, we perceive that a cause must necessarily be in action

Function of sugar, &c. is no longer doubtful.

Some cause must prevent the removal of the free acids in muscles.

at these points, which prevents the removal of the free acids, or, if they are removed, reproduces them at each moment of time.

The conditions of an electrical current are present.

The blood-vessels and lymphatics contain an alkaline fluid, while the surrounding fluid, that of the flesh, is acid; the tissue of which the vessels are composed is permeable for the one or the other of these fluids. Here then are two conditions favourable to the production of an electrical current, and it is far from improbable, that such a current takes a certain share in the vital processes, although its action be not always indicated by proper electrical effects.*

Potash preponderates in the juice of flesh.

I have already mentioned, that the juice of flesh, in all animals, is particularly rich in potash, and that it contains also chloride of potassium, with only traces of chloride of sodium. Now, as every constant peculiarity in the form or in the composition of any part of the body has a significance of its own, this fact, namely, the predominance of salts of

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* Professor H. Buff has, at my request, constructed a pile, consisting of discs of pasteboard moistened with blood, of muscular substance (flesh), and of brain. This arrangement caused a very powerful deviation of the needle of the Galvanometer, indicating a current in the direction from the blood to the muscle.

When water was substituted for the brain, the action was much weaker. The current arising from contact of the blood alone with the platinum was, in this case, in the direction opposite to that of the current just mentioned. The electrician will find nothing surprising in this, since the blood has an alkaline, the flesh an acid, reaction, while the brain has a scarcely perceptible degree of alkalinity.

potash and of chloride of potassium, in the juices of flesh, appears to me to be so much the more worthy of attention, that, in the blood, only proportionally small quantities of the salts of potash, and preponderating quantities of the salts of soda, and of common salt, are present.

Soda preponderates in the blood.

Relative proportions of potash and soda in flesh and blood.

To give a specific direction to our views on the subject of these differences, I have thought it advisable to make some experiments, in which the relative proportions of the compounds of sodium and potassium in the blood, and in the juice of the flesh, was determined comparatively in different animals.

Method employed.

In these determinations the phosphoric acid was precipitated from the fluid of flesh by baryta, the filtered liquid evaporated to dryness, and the residue incinerated. The ashes, thus obtained, are very fusible and of peculiar character, consisting almost entirely of cyanate of potash and cyanide of potassium, exactly as in the ashes of an alkaline urate. When these ashes are dissolved in hydrochloric acid, effervescence ensues, as with a carbonate, from the decomposition of the cyanic acid; a certain amount of sal ammoniac is formed, and hydrocyanic is abundantly disengaged. If bichloride of platinum be now added, to separate the potash from the soda, the precipitate which is formed contains ammonia-chloride of platinum, by which the determination of the potash is rendered inaccurate. It is therefore necessary, before adding the bichloride of platinum, to evaporate the solution of the ashes in hydrochloric acid to dryness, to ignite the residue, and thus expel the sal ammoniac.

Results In the analyses made by Henneberg of the blood of fowls, for which the blood of all the fowls used in my researches on the juices of their flesh was employed, there were obtained, including the chloride of sodium, for 100 parts of soda, 40·8 parts of potash. in the Fowl, The juice of the flesh of the same fowls yielded, for 3·723 gms. of double chloride of platinum and potassium, 0·374 gm. of chloride of sodium.

Ox, Ox-blood gave, for 0·184 gm. of chloride of platinum and potassium, 1·133 gm. of chloride of sodium.

The juice of ox-flesh gave, for 1·933 gm. of chloride of platinum and potassium, 0·2536 gm. of chloride of sodium.

Horse, Horse-blood gave, for 1·351 gm. of chloride of sodium, 0·341 gm. of chloride of platinum and potassium.

The juice of horse-flesh gave, for 4·414 gm. of chloride of platinum and potassium, 0·544 gm. of chloride of sodium.

Fox, The juice from the flesh of a fox, killed in the chase, gave, for 1·474 gm. of chloride of platinum and potassium, 0·250 gm. of chloride of sodium.

and Pike. The juice from the flesh of the pike gave, for 1·964 gm. of chloride of platinum and potassium, 0·065 gm. of chloride of sodium.

Tabular view.

These results, when reduced and tabulated, give—

For 100 parts of soda in the		Potash in the Blood.	Potash in the Flesh.
	Fowl	40·8	384
,,	Ox	5·9	279
,,	Horse	9·5	285
,,	Fox	,,	214
,,	Pike	,,	497

These numbers only approximative.

It is hardly necessary to state, that these numbers only express approximatively the proportions of potash to soda in the flesh, because it is impossible to obtain the juice of the flesh of the ox, horse, and fowl, free from blood and lymph, fluids which contain much soda. Had it been possible to obtain the juice of flesh unmixed with blood and lymph, the proportion of potash to soda would have come out much higher; so much so, indeed, that the conclusion, that salts of soda form no part of that fluid, is not destitute of probability; and if, as is supposed, the lymphatic vessels possess the power of taking up the salts of soda which pass from the capillaries into the substance of the muscles, and returning these salts to the larger blood-vessels, the fact just mentioned admits of a very simple explanation.

The juice of flesh may possibly contain no soda.

The permeability of the vessels of the various fluids must be different.

From the great difference of chemical nature and qualities in the fluids circulating in the different parts of the organism, it follows, that there must be a very remarkable difference in the permeability of the parietes of the vessels for these fluids. Were this permeability in all cases the same, there must have been found as much of the salts of soda and potash in the juice of flesh as in the blood; but the blood of the ox and the fowl contains nearly a third of its whole saline contents of chloride of sodium, while hardly a trace of this compound occurs in the juice of flesh.

Potash preponderates in milk.

The vessels which secrete milk must stand in a similar relation to the blood-vessels; for in the milk of the cow, the salts of potash preponderate very greatly over those of soda, and are present also in much larger quantity than in the saline constituents of blood.

Accumulation of free acids in some morbid states,

In some pathological conditions there has been observed,* at points where bones and muscles meet, an accumulation of free lactic and phosphoric acids, which has never been perceived at those points in the normal state. The solution and removal of the phosphate of lime, and therefore the disappearance of the bones, is a consequence of this state. It is not improbable that the cause, or one of the causes, of this separation of acid from the substance of the muscle, is this—that the vessels, which contain the fluid of the muscles, have undergone a change, whereby they lose the property of retaining within them the acid fluid they contain.

causing the disappearance of the bones.

Importance of chloride of sodium to the blood.

The constant occurrence of chloride of sodium and phosphate of soda in the blood, and that of phosphate of potash and chloride of potassium in the juice of flesh, justifies the assumption that both facts are altogether indispensable for the processes carried on in the blood and in the fluid of the muscles.

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* Schmidt, Annalen der Chemie und Pharmacie, vol. lxi. p. 329.

Use of salt.

Proceeding on this assumption, the necessity for adding common salt to the food of many animals is easily explained, as well as the share which that salt takes in the formation of blood, and in the respiratory process.

Inland plants

It is a fact, now established by numerous analyses, that the ashes of plants, growing at a certain distance from the sea, contain no soda, or only traces of that base.

contain no soda, and little chloride of sodium.

The ordinary potashes of inland countries give most convincing proof of this; for they but rarely contain any carbonate of soda; and when a compound of sodium occurs in them, it is not phosphate or sulphate of soda, but chloride of sodium. Wheat, barley, oats, root-crops, and plants with esculent leaves, in the Odenwald, in Saxony, and in Bavaria, contain only salts of potash, without salts of soda; and if, in several, soda sometimes occurs, chlorine is also present, and both are in the proportion to form sea salt.

The same plants in maritime districts contain soda and potash.

In plants growing in maritime countries near the sea coast, these proportions are altered. Wheat, pease, and the other leguminous plants, in the Netherlands, contain phosphate of potash, and also phosphate of soda, the phosphate of potash, however, always predominating.

Even sea plants contain more potash than soda.

This is the case even in sea plants, living in a medium which contains, compared with its amount of soda or sodium, a mere fraction of potash. All sea plants contain much more potash than soda.

In respect to these two bases, therefore, the food of animals is not in all places of the same quality or composition.

Necessity of chloride of sodium to animals feeding on inland plants.

An animal, feeding on plants which contain phosphates of other bases, along with some compound of soda or sodium, produces in its body the phosphate of soda indispensable to the formation of its blood. But an animal, living inland, obtains in the seeds, herbs, roots, and tubers which it consumes, only salts of potash. It can produce, from the phosphates of lime and magnesia, by decomposition with the salts of potash, only phosphate of potash, the chief inorganic constituent of its flesh; but no phosphate of soda, which is a compound never absent in its blood. Whence, therefore, does it obtain this phosphate of soda? The true answer to this question is given by a study of the action of phosphate of potash on chloride of sodium. Phosphate of potash, with 2 atoms of potash (tribasic phosphate of potash, with 2 atoms of fixed base and 1 atom of water) $= P\,O_5\left\{\begin{matrix}2\,K\,O\\H\,O\end{matrix}\right\}$, is deliquescent, hardly crystallisable, and has a very feeble *alkaline* reaction.

Action of phosphate of potash on chloride of sodium.

When we supersaturate phosphoric acid (tribasic) with potash, and evaporate to crystallisation, a salt is deposited, which has an *acid* reaction $= P\,O_5\left\{\begin{matrix}K\,O\\2\,H\,O\end{matrix}\right\}$. There is no salt which loses half the amount of base it contains so easily as the phosphate of potash. If phosphoric acid be neutralised with potash, and chloride of sodium added to the solution, and the whole left to spontaneous evaporation, a phosphate crystallises, which contains both potash and soda $\left(\text{the tribasic salt } P\,O_5 \left\{\begin{matrix} Na\,O \\ K\,O \\ H\,O \end{matrix}\right\}\right)$ while chloride of potassium is found in the mother liquid.

It is obvious, that phosphate of potash is decomposed when in contact with chloride of sodium; part of the potassium combines with the chlorine, while the sodium replaces it in the phosphate, phosphate of soda being produced.*

In this way we can understand the formation of phosphate of soda in the body of an animal, which obtains in its food, along with phosphate of potash, or earthy phosphates and salts of potash, no compound of soda except chloride of sodium; and when, in inland countries, the food does not contain common salt enough to produce the phosphate of soda necessary for the formation of the blood, then more salt must be added to the food. From the common salt is produced, in this case, by mutual decomposi-

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* It is evident that the tribasic salt above mentioned, $P\,O_5 \left\{\begin{matrix} Na\,O \\ K\,O \\ H\,O \end{matrix}\right\}$ may equally well be represented as a double salt, composed of phosphate of soda and phosphate of potash.

$$2\left(P\,O_5 \left\{\begin{matrix} Na\,O \\ K\,O \\ H\,O \end{matrix}\right\}\right) = P\,O_5 \left\{\begin{matrix} 2\,Na\,O \\ H\,O \end{matrix}\right\} + P\,O_5 \left\{\begin{matrix} 2\,K\,O \\ H\,O \end{matrix}\right\}$$

W. G.

tion with phosphate of potash or with earthy phosphates, the phosphate of soda of the blood.

The phosphate of soda in the blood cannot be replaced by phosphate of potash.

That phosphate of soda is indispensable to the normal constitution of the blood, and that the processes which go on in that fluid cannot be replaced by phosphate of potash, seems to me to be an opinion fully justified by the properties of these two salts.

Importance of ascertaining the true cause of the alkalinity of the blood.

Through the blood, the carbonic acid formed in the body is conveyed out of it, and the alkaline quality of the blood has a very decided share in its property of thus taking up carbonic acid; as, on the other hand, the chemical nature of the compound, on which the alkaline reaction of the blood depends, exerts the most marked influence on the power of the blood, again to give off the carbonic acid which it had absorbed.

Relation of blood to carbonic acid gas.

Experiments of Scheerer.

It is known that freshly-drawn blood, by mere agitation with air, by passing through it a current of hydrogen gas, or in the vacuum of the air-pump, gives off carbonic acid. From the experiments of Scheerer, at which I had the opportunity of being present, and of others, it is known, moreover, that, for example, the clear serum of ox blood, free from blood corpuscules, absorbs nearly twice its volume of carbonic acid, that is, as much more as the same bulk of water can absorb at the same temperature. The greater absorbing power of the serum is determined by a chemical attraction, by a substance, which has an alkaline reaction. In fact, it is observed, that, when this alkaline reaction is destroyed, when acetic acid is added to the blood saturated with carbonic acid, the excess of carbonic acid is at once given off. But the same thing happens when this blood is agitated with gases, such as hydrogen, for a long time, and the gases renewed from time to time.

Blood, when not saturated with carbonic acid, gives off, in vacuo, nearly 5 p. c. of its volume of that gas; the addition of acetic acid increases the quantity of the carbonic acid disengaged; but even under these circumstances not more than half its volume of carbonic acid can be obtained from blood.

The serum of blood contains no carbonate of soda.

Had the greater absorptive power of the serum of blood for carbonic acid been dependent on the presence of carbonate of soda, and its conversion into bicarbonate of soda, this would imply that the blood must contain at least its own volume of carbonic acid in the form of neutral carbonate of soda. If blood contained its own volume of carbonic acid in the form of neutral carbonate, and no free carbonic acid, this blood would absorb exactly twice its volume of carbonic acid (one volume to form bicarbonate, the other to saturate the liquid as it would an equal bulk of water), and the addition of acids which decompose the carbonate of soda, must, in that case, disengage a volume of carbonic acid equal to twice the volume of the blood. The acid would, in fact, disengage three volumes of carbonic acid, one of which is retained by the liquid. In the experiments of Scheerer, serum of blood, which had absorbed twice its volume of carbonic acid, only yielded half as much carbonic acid as ought to have been given off on the above supposition. There was less than one volume of free carbonic acid present in the serum, and the liquid retained, for that reason, a proportionally greater quantity of carbonic acid.*

The author's experiments to prove this.

When 2,000 cubic centimetres of ox-blood, mixed with twice their volume of water, are heated to boiling, and the coagulum pressed out, we obtain about 2,000 c. c. (1-3rd of the whole liquid) of an alkaline liquid. If the alkaline reaction of this liquid arises from carbonate of soda, these 2,000 c. c. must contain 1-3rd of the whole carbonate of soda contained in that volume of blood. When concentrated to 1-3rd by evaporation, this liquid must contain exactly as much, if concentrated to 1-6th, twice

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* Annalen der Chemie und Pharmacie, vol. xl. p. 30.

I.	60	vols. of serum absorbed	124	vols. of carbonic acid.
II.	56	,,	111	,,
	116		235	

After the addition of 30 cubic centimetres of acetic acid to the first portion, and of 28 c. c. to the second portion of serum, in all after the addition of 58 c. c. of acetic acid, there were disengaged, from 174 vols. of the mixture (116 vols. of serum and 58 vols. of acetic acid) 89 vols. of carbonic acid. Had the blood contained its own volume of carbonic acid in the form of neutral carbonate of soda, it must have given off 177 vols. of carbonic acid; that is, 235—58 (the volume which would be retained by the acetic acid). According to these experiments, the actual amount of carbonic acid present in the blood is calculated to be 28 per cent. of its volume.

as much, to 1-12th, four times as much, and to 1-24th, eight times as much, &c. carbonate of soda as an equal volume of blood.

Highly concentrated serum absorbs carbonic acid,

Now, I have concentrated this liquid to 1-500th of its volume, in which state it must, on the supposition formerly mentioned, contain 166 times as much carbonate of soda as an equal volume of blood, if that salt were an ingredient of blood. When brought in contact with carbonic acid, this concentrated liquid absorbed 3 times its own volume; 20 c. c. absorbed 60 c. c. of carbonic acid. Now it is certain that if this absorptive power had been dependent on the presence of carbonate of soda, the solution, saturated with carbonic acid, must have given off, when mixed with acids, 3 times its original volume of carbonic acid, of which 1-3rd would be retained by the liquid. From 20 c. c., therefore, of the concentrated liquid, there should have been obtained 40 c. c. of free carbonic acid. *But this liquid, when acted on by acids, gave off no appreciable trace of carbonic acid gas.*

but does not give off a trace when acids are added to it.

According to the observations of Marchand, this liquid is not free from carbonic acid, when it has been mixed with another acid, for by heating it carbonic acid is expelled. But even on the most favourable supposition, that is, if we admit that the liquid is saturated with carbonic acid, it is obvious that no more carbonate of soda can be contained in it than corresponds to the volume of carbonic acid required to saturate the 1-166th part of the volume

7·5 cubic inches of serum cannot contain more than 2-5ths of a grain of carbonate of soda, of the serum. This amounts, for 1,000 c. c. of serum, to so much soda as is saturated by 6 c. c. of carbonic acid gas = 0·026 gm. of carbonate of soda, or 2-5ths of a grain.

but it absorbs at least 166 times more carbonic acid than this carbonate could.

The serum of blood absorbs, therefore, 166 times more carbonic acid than could be absorbed by the very largest proportion of carbonate of soda which it can be supposed to contain; and consequently the carbonate of soda, if it be present at all in the *liquor sanguinis*, can have but a most insignificant share in the absorptive power of that fluid for carbonic acid.

This depends on the phosphate of soda.

As the study of the serum and the analysis of the ashes of blood prove, the alkaline quality of the blood depends on the presence of phosphate of soda. Indeed, it may well be asked, from what source can carbonate of soda, if we suppose it to be present, be derived, in the blood of a man living on bread and flesh, or of an animal feeding on flesh, since in these kinds of food the alkalies and phosphoric acid are present in the proportion in which they form salts with 2 and with 3 atoms of fixed base?*

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* The experiments of Erdmann on the incineration of wheat (Annalen der Chemie und Pharmacie, vol. liv. p. 354) leave no doubt, that the tribasic phosphates (with 3 atoms of fixed base) in these ashes are derived from the action of carbon on the phosphates with 1 and 2 atoms of fixed base, at a red heat, or from the decomposition of chloride of sodium in contact with these phosphates. In the analyses of Henneberg, where this last cause was avoided, the formation of pyrophosphate of soda proves, that the blood of fowls contains tribasic phosphate of soda with 2 atoms of fixed base ($P O_5$, 2 Na O, H O).

Remarkable properties of phosphate of soda.

There is no known salt, the chemical characters of which approach more closely to those of the serum of blood, than the phosphate of soda; there is none more fitted for the absorption and entire removal from the organism of carbonic acid. This salt behaves towards carbonic acid exactly as neutral carbonate of soda; its aqueous solution absorbs carbonic acid gas with the same facility, but with this difference, however, that under the influence of the same causes which decompose the neutral carbonate, and the bicarbonate of soda, this solution gives off the carbonic acid which it has absorbed much more easily, and also more completely, since it does not, like soda, in its conversion from bicarbonate into neutral carbonate, retain any portion of carbonic acid.

It not only absorbs, but also gives off, carbonic acid with great facility.

When carbonic acid gas is placed in contact with a solution of 1 part of dry phosphate of soda (PO_5, 2 Na O, H O), in 100 parts of water, twice as much carbonic acid is absorbed as an equal volume of water, at the same temperature, can take up.*

By simple agitation with air, or by diminution of the atmospheric pressure, 2-3rds of the absorbed carbonic acid are given off at the ordinary temperature; by contact with fresh carbonic acid, these 2-3rds are immediately again absorbed.†

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* A solution of phosphate of soda, saturated with carbonic acid, may be recommended as one of the pleasantest saline purgatives.

Experiments.

† A solution of 1 part of dry phosphate of soda, PO_5, 2 Na O,

Uses of the phosphate of soda in blood.

By the spontaneous evaporation in the air of the solution of phosphate of soda, saturated with carbonic acid, the whole of the carbonic acid is given

H O, in 100 parts of water, when agitated with pure carbonic acid gas, free from atmospheric air, absorbed:

	I.	II.	III.	IV.
Solution, cubic centimetres	59	38	62	56
Carbonic acid absorbed c. c.	104	77	114	112
100 vols. of the solution absorb, therefore	176	203	183	200

Mean amount of gas absorbed by 100 vols. of solution = 190 vols.

The water which had been used for the solution was treated in the same way, and absorbed:

	I.	II.	III.
Water, c. c.	104	75	54
Carbonic acid absorbed c. c.	98	64	52
100 vols. of water absorb, therefore	95	85	98

Mean amount of gas absorbed by 100 vols. of water = 92 vols.

A portion of the solution of phosphate of soda, as above, was saturated with carbonic acid, and then agitated with repeated portions of air, as long as any carbonic acid was expelled. The solution was now placed in contact with pure carbonic acid gas, and absorbed:

	I.	II.	III.	IV.
Solution, c. c.	62	67	68	89
Carbonic acid absorbed c. c.	88	91	99	116
100 vols. of solution absorb, therefore ...	143	134	145	130

Mean amount absorbed by 100 vols. of solution = 138.

A similar solution of phosphate of soda, saturated with carbonic acid, was deprived, as completely as possible, of that gas, under the receiver of the air-pump, being left for two hours under a pressure of $2'''$. When again placed in contact with carbonic acid, it absorbed:

	I.	II.	III.
Solution, c. c....................	74	80	70
Carbonic acid absorbed c. c. ...	99	107	96
100 vols., therefore, absorb ...	120	133	137

Mean amount absorbed by 100 vols. of solution = 130.

off, and the phosphate is left, with all its original properties, including its alkaline reaction.

Action of carbonic acid on the blood.

When carbonic acid is taken up by the blood, there is established between the phosphoric and carbonic acids an equilibrium, similar to that existing in the juice of flesh between the phosphoric and lactic acids. In the same way as these last divide between them the potash of the juice, so do the carbonic and phosphoric acids divide between them the soda of the blood. There can be no circumstances more favourable to the separation of one or other of the two acids.

If we assume, that the carbonic acid seizes a portion of the soda, we may imagine that the phosphoric acid, previously combined with this portion of base, is expelled from the place it originally occupied, and thus set free; but it does not yet, on that account, separate from the compound. We can say that the carbonic acid is converted into carbonate of soda, only when the free phosphoric acid has been removed, and employed in another quarter; but in point of fact, this phosphoric acid, thus displaced, is always present, and retains, unimpaired, its power of again combining with the soda. The slightest cause, coming in aid of its affinity, so as to give it the preponderance (and to this category belong all causes which diminish the affinity of carbonic acid for soda), suffices to displace the carbonic acid, and to reproduce the original compound. Agitation with air; the spontaneous evaporation of the water, in which the compound is dissolved; the diminution of the atmospheric pressure; all these causes, which have no effect on neutral carbonate of soda, produce decomposition, and cause the separation of the carbonic acid, taken up by the phosphate of soda in the blood. In this manner, the amount of carbonic acid in the blood is kept at a constant value. If more carbonic acid enter the blood from the body, more phosphoric acid is set free in proportion, and thereby a more easy and complete separation of the carbonic acid in the lungs is secured. If more soda be taken up, then a part of the carbonic acid, which would otherwise have escaped by the lungs and skin, is expelled by the urinary passage in the form of carbonate of soda.

The amount of carbonic acid in the blood is kept uniform.

It is easy to foresee, that a more exact study of the influence which alkalies, salts, and mineral acids exert on the respiratory process in the normal state, must lead to the most beautiful and valuable results in regard to their employment in various diseases.

Influence of acids, alkalies, and salts on respiration.

It has already been pointed out, that in the juice of flesh the amount of phosphate of lime, compared *with that of phosphate of magnesia*, is very trifling. In fact, the juice of ox-flesh contains so little lime, that the quantity obtained from many pounds of flesh amounted only to a few milligrammes (1 milligramme = 1-75th of a grain, nearly); but in the juice of the flesh of fowls, the relative proportions of these two bases admitted of more exact determination.

The juice of flesh contains very little *lime*.

The juice of fowl's flesh was precipitated by

Proportion of lime to

magnesia in the juice of fowl.

baryta, the precipitate dissolved in hydrochloric acid, the baryta separated by sulphuric acid, and then the phosphoric acid removed by means of sesqui-chloride of iron and ammonia. The lime and magnesia then remained in solution. There were obtained 0·72 gm. of carbonate of lime, and 0·431 gm. of phosphate of ammonia and magnesia; or for 10 parts, by weight, of lime, 39·2 parts of magnesia.

Proportion of alkaline phosphates.

The proportion of the phosphoric acid combined with alkalies, to that united with magnesia, in the juice of ox-flesh, was determined in the following manner. The precipitate formed by baryta contains all the phosphoric acid, partly combined with baryta (as PO_5, $3 BaO$), partly with magnesia (as PO_5, $3 MgO$). This precipitate was decomposed by sulphuric acid, and the liquid, filtered from the sulphate of baryta, was precipitated by ammonia. In this way the magnesia was thrown down, in the form of the usual double phosphate. The liquid filtered from this precipitate contained the phosphoric acid originally combined with alkalies, and when mixed with sulphate of magnesia yielded a new precipitate of the same double phosphate of ammonia and magnesia. The weight of the first precipitate was to that of the second as 0·2782 to 0·974, or as 1 to 3·5. For 2 atoms of phosphoric acid, therefore, combined with magnesia, the juice of ox-flesh contains 7 atoms of phosphoric acid, combined with alkalies, chiefly potash. In another experiment the proportion was found to be as 1 to 3·2.

SECTION III.

Practical Application of the Results of the Foregoing Investigation.

Effect of boiling on flesh.

With reference to a future chemistry of alimentary substances, it appears from these researches, that by the boiling of flesh an essential change in its composition is effected. According to the duration of the boiling, and the amount of water employed, there takes place a more or less perfect separation of the soluble from the insoluble constituents of flesh. The water in which flesh has been boiled contains soluble alkaline phosphates, lactates, and inosinates, phosphate of magnesia, and only traces of phosphate of lime; the boiled flesh contains chiefly, with the fibrine, &c., the insoluble inorganic constituents, phosphate of lime and phosphate of magnesia.

It is obvious, that if flesh, employed as food, is again to become flesh in the body, if it is to retain the power of reproducing itself in its original condition, none of the constituents of raw flesh ought to be withdrawn from it during its preparation for food. If its composition be altered in any way, if one of the constituents which belong essentially to its constitution be removed, a corresponding variation must take place in the power of that piece of flesh to reassume in the living body the original form and quality, on which its properties in the living organism depend.

It follows from this, that boiled flesh, when eaten without the soup formed in boiling it (the *bouilli* without the *bouillon*) is so much the less adapted for nutrition, the greater the quantity of the water in which it has been boiled, and the longer the duration of the boiling.

Boiled meat without the soup is not nutritious.

When finely chopped flesh is extracted with cold water, it loses the whole of the albumen contained in it. The fibrinous residue, after being well washed with cold water, if boiled with water is found to be perfectly tasteless; it is clear that all the sapid and odorous constituents of flesh exist in the flesh itself in the soluble state, and consequently, when it is boiled, are transferred to the soup. The smell and taste of roasted flesh arise from the soluble constituents of the juice, which have undergone a slight change under the influence of the higher temperature. Flesh, which has been rendered quite tasteless by boiling with water, acquires the taste and all the peculiarities of roasted flesh, when it is moistened and warmed with a cold aqueous infusion of raw flesh which has been evaporated till it has acquired a dark brown colour.*

Cold water extracts all the soluble constituents of flesh.

Importance of their constituents.

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* *Note by the Editor.*—The *Stock* so much used by good cooks, and for preparing which, generally from beef, but often also from mixed flesh, such minute directions are given in books on cookery, is essentially such a concentrated infusion of flesh as that described in the text. It is usually made by long boiling, but this is not indispensable. The addition of stock to any dish not only improves the flavour, but often restores the soluble matter removed in previous operations, such as boiling, &c., and thus renders it much more wholesome and nutritious than it would

All sorts of flesh are alike in this respect; the sapid and odorous constituents are present in the roasted flesh in solution, or in the soluble state. The liquid which is obtained by lixiviation of different kinds of flesh with cold water, after it has been heated to boiling, and the albumen thus coagulated, possesses, in all cases, the well-known general flavour of soup; but each kind, individually, has, besides this, a peculiar taste, which recalls the taste and smell of the different sorts of flesh; insomuch that, when to boiled beef, for example, the concentrated cold aqueous infusion of roe-deer venison or of fowl is added, and the whole warmed together, the beef cannot then be distinguished by the taste from the venison or the fowl. A slight addition of lactic acid (a very little fresh sauerkraut, for example), or of chloride of potassium, which is an invariable constituent of all infusions of flesh, heightens the piquancy of the flavour of meat: as

The flavour of soup, and of the different kinds of flesh,

depends on the soluble matter.

It is heightened by lactic acid or by chloride of potassium.

otherwise be. A good cook judges of almost every thing by the taste, and we see in the text the explanation of this, since the sapid constituents are among the most valuable parts of the food. We see, also, that in cookery, as in other domestic arts, long experience and observation have led, in many instances, to the most judicious practice. It is the want of a scientific basis, however, for the culinary art, that has given rise to many absurd and hurtful methods of preparing food; as, for example, the very common English practice of boiling meat or vegetables with a very large quantity of water, which is thrown away, and with it the whole, or nearly the whole, of the soluble matter. The advantage of stewing over boiling depends on the fact, that in the former all the soluble matter is retained in the sauce or juice, which is served with the meat.—W. G.

on the other hand, an alkaline liquid, or the addition of blood, renders the soup or infusion of meat utterly insipid and mawkish.

The flesh of old animals contains little albumen,

From all the different kinds of flesh we obtain, by lixiviation with cold water, the whole of the albumen present in them, in the dissolved state. The quantity of coagulated albumen, which separates from the infusion when heated, is very different in different specimens, and seems to stand in a certain relation to the age of the animal. The flesh of old animals is proportionally poor in albumen, and, on the other hand, it is so much the richer in fibrine. From the flesh of an old horse, for example, there was not obtained the tenth part of the quantity of albumen which was furnished by an equal weight of ox-flesh.

but much fibrine.

Muscular fibre.

The muscular fibre, in the natural state, is everywhere surrounded by a liquid containing dissolved albumen. When this is removed, the fibre, in all animals, is of the same quality. The well-washed muscular fibre, when boiled with water, becomes hard and horny, and this the more the longer it is boiled. It is obvious, therefore, that the tenderness of boiled or roasted meat depends on the quantity of the albumen deposited between the fibres, and there coagulating; for the contraction or hardening of the fibrinous fibres is thereby to a certain extent prevented. This quality, tenderness, however, also depends on the duration of the boiling; for the albumen also becomes harder by

Its tenderness depends on the albumen of the juice.

continued boiling, without, however, assuming a tough consistence.

Action of hot water on flesh.

The influence of hot water on the quality of the meat which is boiled with it, and of the soup obtained, hardly requires, after what has been said, any further elucidation.

Best method of boiling meat.

If the flesh intended to be eaten be introduced into the boiler, when the water is in a state of brisk ebullition, and if the boiling be kept up for some minutes, then so much cold water added as to reduce the temperature of the water to 165° or 158°, and the whole kept at this temperature for some hours, all the conditions are united, which give to the flesh the quality best adapted to its use as food.

When it is introduced into the boiling water, the albumen immediately coagulates from the surface inwards, and in this state forms a crust or shell, which no longer permits the external water to penetrate into the interior of the mass of flesh. But the temperature is gradually transmitted to the interior, and there effects the conversion of the raw flesh into the state of boiled or roasted meat. The flesh retains its juiciness, and is quite as agreeable to the taste as it can be made by roasting; for the chief part of the sapid constituents of the mass is retained, under these circumstances, in the flesh.

Temperature required.

If we reflect that the albumen of the juice of flesh begins to coagulate at a temperature of 105·5° and that it is completely coagulated at 140° (Berzelius), it might be supposed that it would not be necessary, in the cooking of flesh, to expose it to a higher temperature than 140°. But, at that temperature, the colouring matter of the blood is not yet coagulated; the flesh, indeed, is eatable, but when it contains blood, it acquires, under these circumstances, a bloody appearance, which it only loses, when it has acquired, throughout the whole mass, a temperature of 150° to 158°.

Underdone meat.

In the interior of a very large piece of flesh, which has been boiled or roasted, we can tell with certainty the temperature attained in the different parts, by the colours which they present. At all those parts which appear bloody, the temperature has not reached 144°. In the boiling or roasting of poultry, the flesh of which is white, and contains little blood, the temperature of the inner parts, when the flesh has been well cooked, seldom exceeds 130° or 140°. The flesh of poultry or game is therefore sooner dressed (ready, or done as it is called) than flesh which contains much blood, such as beef or mutton.

Poultry is sooner done than beef or mutton.

By enveloping small pieces of flesh (as is often done in the case of small birds, such as quails, ortolans, larks, and even partridges) with a covering of lard, the extraction of the sapid constituents from the flesh by its juices, and the evaporation of the water, which causes hardening, are prevented; and the surface, as well as the subjacent parts, are kept in the tender state, which is otherwise only found in the inner portions of large masses of flesh.

Use of a covering of lard in roasting.

How meat is to be boiled to obtain good soup.

The introduction of the piece of raw flesh into water already boiling is the best process for the dressing of the meat, but the most unfavourable for the quality of the soup. If, on the contrary, the piece of raw meat be placed in cold water, and this brought *very gradually* to the boiling point, there occurs, from the first moment, an interchange between the juices of the flesh and the external water. The soluble and sapid constituents of the flesh are dissolved in the water, and the water penetrates into the interior of the mass, which it extracts more or less completely. The flesh loses, while the soup gains, in sapid matters; and, by the separation of albumen, which is commonly removed by skimming, as it rises to the surface of the water when coagulated, the surface of the meat more particularly loses its tenderness and shortness (as it is called), becoming tough and hard. The thinner the piece of flesh, the more completely does it acquire the last-mentioned qualities; and if in this state it be eaten without the soup, it not only loses much of its nutritive properties, but also of its digestibility, inasmuch as the juice of the flesh itself, the constituents of which are now found in the soup, are thus prevented from taking part in the digestive process in the stomach. The soup, in fact, contains two of the chief constituents of the gastric juice.

Meat from which soup has been made is neither nutritious nor digestible without the soup.

Gelatine is not the source of the strength

It has long been customary to ascribe to the gelatinous matter dissolved during boiling, which gives to concentrated soup the property of forming or flavour of soup.

a jelly, the chief properties or peculiarities of the soup; but there cannot be a greater mistake. The simplest experiments prove that the amount of dissolved gelatine in well-prepared soup is so small, that it cannot come into calculation in explaining its properties. Gelatine is, in itself, quite tasteless, and consequently the taste of the soup cannot be derived from it.

Experiments to ascertain the amount of gelatine dissolved in the making of soup.

In order to determine the amount of gelatinous matter dissolved in the boiling of flesh under the most favourable circumstances, finely-chopped meat was exhausted with cold water, pressed as dry as possible, and the residue, fibres and membranes, boiled for five hours with ten times its weight of water, the liquid pressed out from the insoluble matter, and evaporated to dryness in the water-bath. The soup thus obtained, from beef and veal, was tasteless, or rather had a peculiar mawkish taste, which to most persons was nauseous. That from veal gelatinised when reduced to half, that from beef when reduced to 1-16th of its original volume.

3,000 grammes of lixiviated veal (6 lbs.) yielded, under these circumstances, after five hours' boiling, 47·5 gms. of matter dissolved by the water (gelatine, &c.).

1,000 gms. of lixiviated beef (2 lbs.) yielded, in the same way, 6 gms. of gelatine, &c.

It appears from these experiments, that the muscular fibres and membranes of the calf and ox, in that state in which they present to the dissolving energy of the water the largest surface, and after five hours' boiling, yielded, the former only 1·576 per cent., the latter 0·6 per cent. of soluble matter, of which the gelatine certainly does not constitute one-half, since some part or constituent of the fibrine is also dissolved under these circumstances.

Those constituents of 1,000 gms. or 2 lbs. of beef, which are soluble in cold water, weighed, when dry, 60 gms., of which 29·5 gms. were albumen.

Amount of matter dissolved from meat by hot and cold water.

Under the most favourable circumstances, therefore, we obtain, from 1,000 gms. of beef—

		By Boiling.	
Soluble in cold water ...	60	Coagulated Albumen ...	29·5
		In the solution...........	30·5
Insoluble in cold water...	170	Gelatine	6·0
		Fibres, Membranes, &c.	164·0
Fat	20		
Water	750		
	1,000		

It follows, that boiling water, when allowed to act for five hours on finely-chopped flesh, yet does not dissolve more than the fifth part of the matters soluble in cold water, even after the albumen has been separated by heating the cold infusion; and that this fifth part, besides, does not consist of pure gelatine, but contains all the products dissolved out of the muscular fibres by long boiling.

Consequently the efficacy of soup, or decoction of flesh, cannot depend on the gelatine it contains.

More soluble matter in poultry than in beef.

The flesh of poultry contains, for equal weights, more of the matters soluble in cold water, and remaining dissolved after the coagulation of the albumen, than beef does.

From 1,000 gms. of fowl, cold water takes up 80 gms. of soluble matter, of which 47 gms. consist of albumen, and 33 gms. remain dissolved in the liquid when boiled.

The nutritious and sapid ingredients of soup exist ready formed in flesh.

The characters of flesh described in the preceding paragraphs at once suggest the best method of preparing, in the short space of a few minutes, the strongest and most highly-flavoured soup; and any one may convince himself, by the simplest experiments, of the truth of the assertion made by Proust, that those constituents of soup, on which its taste and other properties depend, exist ready formed in the flesh, and are not in any way products of the operation of boiling.

Best method of preparing soup.

When 1 lb. of lean beef, free of fat, and separated from the bones, in the finely-chopped state in which it is used for beef sausages or mince-meat, is uniformly mixed with its own weight of cold water, slowly heated to boiling, and the liquid, after boiling briskly for a minute or two, is strained through a towel from the coagulated albumen and the fibrine, now become hard and horny, we obtain an equal weight of the most aromatic soup, of such strength as cannot be obtained, even by boiling for hours, from a piece of flesh. When mixed with salt and the other usual additions, by which soup is usually seasoned, and tinged somewhat darker by means of roasted onions or burnt sugar, it forms the very best soup which can in any way be prepared from 1 lb. of flesh.

Influence of the brown colour of soup on the judgment we form as to its strength and flavour:

The influence which the brown colour of this soup, or colour in general, exercises on the taste, in consequence of the ideas associated with colour in the mind (ideas of strength, concentration, &c.), may be rendered quite evident by the following experiment. The soup, coloured brown by means of caramel, is declared by all persons to have a much stronger taste than the same soup, when not coloured; and yet the caramel, in point of fact, does not in any way actually heighten the taste.

Extract of meat, or true portable soup.

If we allow the flesh to boil for a long time with the water, or if we boil down the soup, it acquires, spontaneously, when concentrated to a certain point, a brownish colour and a delicate flavour of roast meat. If we evaporate it to dryness in the water-bath, or if possible at a still lower temperature, we obtain a dark brown, soft mass, of which half an ounce suffices to convert 1 lb. of water, with the addition of a little salt, into a strong, well-flavoured soup.

Portable soup of commerce is nearly pure gelatine.

The tablets of so-called portable soup prepared in England and France are not to be compared with the extract of flesh just mentioned; for these are not made from flesh, but consist of gelatine, more or less pure, only distinguished from bone gelatine by its higher price.*

Beef yields $\frac{1}{32}$nd of its weight of extract of beef.

From 32 lbs. of lean beef, free from bones and fat (8 lbs. *dry meat and* 24 lbs. *water*), *there is obtained* 1 lb. of true extract of flesh, which, from its necessarily high price, can hardly become an article of commerce; but if the experience of military surgeons agrees with that of Parmentier, according to whom "The dried extract of flesh, as an article of "provision in the train of a body of troops, supplies "to severely wounded soldiers a restorative, or "roborant, which, with a little wine, immediately "revives their strength, exhausted by great loss of "blood, and enables them to bear the transport to "the nearest hospital,"† it appears to me to be a matter of conscience to recommend to the attention of governments the proposal of Parmentier and of Proust.

Extract of meat recommended as a restorative for wounded soldiers.

Characters of genuine and of false extract of meat.

Now that the composition of the extract of flesh is somewhat more accurately known, it ought to be easy for every well-informed apothecary to distinguish the genuine from the false. Of the true extract, nearly 80 per cent. is soluble in alcohol of 85 per cent., while the ordinary tablets of portable

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* *Note by the Editor.*—I have seen some specimens of portable soup, which, although consisting chiefly of gelatine, yet had a strong flavour of soup, and probably, therefore, contained a certain proportion of extract of flesh.—W. G.

† See Proust, Annales de Chimie et de Physique. Third Series, vol. xviii. p. 177.

soup rarely yield to that menstruum more than 4 or 5 per cent. The presence of kreatine and kreatinine, the latter of which is instantly detected by the addition of chloride of zinc to the alcoholic solution, as well as the nature of the salts left on incineration, which chiefly consist of soluble phosphates, furnish sufficient data for judging of the quality of the true extract of flesh.

Extract of meat recommended for ships and fortresses, as an addition to salt meat.

I consider this extract of flesh as not less valuable for the provisioning of ships and fortresses, in order to preserve the health of the crew or garrison, in those cases where fresh meat and vegetables are wanting, and the people are supported by salt meat.

Salting of meat.

It is universally known that in the salting of meat, the flesh is rubbed and sprinkled with dry salt, and that where the salt and meat are in contact, a brine is formed, amounting in bulk to 1-3rd of the fluid contained in the raw flesh.

The brine of salt meat contains the ingredients of the extract;

I have ascertained that this brine contains the chief constituents of a concentrated soup or infusion of meat, and that, therefore, in the process of salting, the composition of the flesh is changed, and this, *too, in a much greater degree than occurs in boiling.* In boiling, the highly nutritious albumen remains in the coagulated state in the mass of flesh, but, in salting, the albumen is separated from the flesh; for when the brine from salted meat is heated to boiling, a large quantity of albumen separates as a coagulum. This brine has an acid reaction, and gives with ammonia a copious precipitate of the double phosphate of ammonia and magnesia. It contains also lactic acid, a large quantity of potash, and kreatine, which, although I could not separate that body from the large excess of salt, may be safely concluded to be present, from the presence of kreatinine. The brine, when neutralised by lime, gives, after the salt has been crystallised out, a mother liquid, from which, after some time, when alcohol and chloride of zinc are added to it, the double chloride of zinc and kreatinine, so often mentioned in the former part of this work, is deposited.

Phosphates, lactic acid, kreatine, and kreatinine.

It is now easy to understand that in the salting of meat, when this is pushed so far as to produce the brine above mentioned, a number of substances are withdrawn from the flesh, which are essential to its constitution, and that it therefore loses in nutritive quality in proportion to this abstraction. If these substances be not supplied from other quarters, it is obvious that a part of the flesh is converted into an element of respiration certainly not conducive to good health. It is certain, moreover, that the health of a man cannot be permanently sustained by means of salted meat, if the quantity be not greatly increased, inasmuch as it cannot perfectly replace, by the substances it contains, those parts of the body which have been expelled in consequence of the change of matter, nor can it preserve in its normal state the fluid distributed in every part of the body, namely, the juices of the flesh. A change in the quality of the gastric juice, and consequently in that

Salted meat is deficient in nutritive quality.

Causes of this.

of the products of the digestive process, must be regarded as an inevitable result of the long-continued use of salted meat; and if during digestion the substances necessary to the transformation of that species of food be taken from other parts of the organism, these parts must lose their normal condition.

Effects produced on meat by salt containing chlorides of calcium and magnesium.

In my experiments on the salting of meat, I used at first a species of salt which subsequently proved on examination to contain a considerable proportion of chloride of calcium and chloride of magnesium. I was induced to examine the salt by observing that the brine obtained from meat salted with it contained only traces of phosphoric acid. The external aspect of the salted flesh sufficiently explained this unexpected fact; for it was covered as if with a white froth, consisting chiefly of phosphate of lime and phosphate of magnesia. The earthy salts of the sea salt had entered into mutual decomposition with the alkaline phosphates of the juice, producing phosphates of lime and magnesia, of which only very small quantities could be dissolved in the acid brine.

Meat thus salted may be less unwholesome.

In the use of a salt, rich in lime and magnesia, there may thus be a cause which renders the meat salted with it less injurious to the system. For it is plain that when, along with such meat, vegetables are eaten which are rich in potash (and this is the case with all esculent vegetables), the conditions are present which determine the reproduction, during digestion, of the deficient alkaline phosphates. That these latter salts may actually be formed under such circumstances, is shown by the analysis of milk, a fluid rich in alkaline phosphate, compared with that of the fodder or food of graminivorous animals, which last contains no alkaline phosphates, but phosphates of lime and magnesia along with salts of the alkalies with other acids.

Flesh compared with other kinds of animal food.

When we compare flesh with other animal food, such as eggs and cheese, the difference is striking, and the difficult digestibility of the latter, when compared with flesh, unquestionably depends on the difference in their composition.

The soluble constituents of the muscles must be essential to their functions.

If we consider that the juice of flesh, in all animals yet examined, possesses a constant character; that, exclusive of those constituents which are derived from the blood unavoidably mixed with it, as well as of small quantities of odorous and sapid substances on which the characteristic secondary or by-taste of the juice or soup of the flesh in each kind of animal depends, the juice of ox-flesh is in no way distinguishable from that of the fox, it seems justifiable to conclude, that the quantity and the nature of the soluble constituents in the muscular system are essential to the functions of the muscles. It appears further to follow, that in judging of the nutritive qualities of any kind of food, the composition of the blood cannot be selected as the proper datum from which to argue, because there are a number of factors which must be brought into the

Nutritive value of animal food cannot be ascertained from the composition of the blood alone.

calculation, and which are either wanting in the blood, or present in it only in trifling quantity.

Lactic acid found in the gastric juice of dogs by Lehmann.

Some experiments have lately been made by Lehmann on the gastric juice of dogs, fed on bones and lean horse-flesh, which fluid he has studied more minutely than had previously been done. He obtained from it a crystallised salt of magnesia, combined with an organic acid, not containing nitrogen. This salt yielded 16·6 p. c. of magnesia, and 21 p. c. of water of crystallisation. Now that we know that lactic acid forms a constituent of the chief mass of the body, it is evident that Lehmann's magnesian salt, which agrees with lactate of magnesia in the proportion of base and of water of crystallisation, really was lactate of magnesia. In that case the gastric juice contains lactic acid, and thus the problem of the digestive process in the stomach would appear, in its chemical aspect, to be completely solved.

The digestive process in the stomach is now cleared up.

The gastric juice similar to the juice of flesh.

The experiments of all who have studied the gastric juice agree in this, that that fluid contains, along with an organic acid, free phosphoric acid or an acid phosphate, and in this respect its similarity with the juice of the muscles is strikingly obvious. That portion of the gastric juice which is soluble in alcohol is, in its reaction, identical with the alcoholic extract of soup, as Tiedemann and Gmelin have already shown; and the soup or infusion of meat, free from gelatine and fat, the preparation of which I have described (*ante*, p. 131), may perhaps admit

The soup

of being employed as a valuable remedy for many dyspeptic patients, with a view to increasing the activity of the stomach, and promoting digestion. Again, if the blood or the muscular substance of emaciated convalescents cannot supply the matters necessary for digestion in sufficient quantity for a rapid reproduction of the lost strength (that is, the lost parts of the organism) the benefit derived from well-made soup during convalescence admits of a simple explanation.

formerly described proposed as a remedy in dyspepsia.

Its value to convalescents.

Finally, when we recollect, that lactic and phosphoric acids, at temperatures in which hydrochloric, acetic, and butyric acids are volatilised, are almost fixed, we can explain how it happens that in many cases hydrochloric acid, in others acetic or butyric acid, has been obtained by distilling the gastric juice. Acetates, butyrates, and even chloride of sodium, are decomposed by lactic acid, as well as by acid phosphates, in these *circumstances*, and the occurrence of the one or the other of the more volatile acids *must vary with the amount of the lactic or* phosphoric acid present in the gastric juice, and the *amount also of their salts in the same fluid.*

Origin of the hydrochloric and other volatile acids obtained by distilling the gastric juice.

CONCLUSION.

I think it right to state, distinctly, that I am far from considering the nature and quality of the substances occurring in the juice of flesh as fully

These researches only the commencement of a more complete investigation.

ascertained by the investigation contained in the preceding pages. On the contrary, I am of opinion, that it ought only to be regarded as the commencement of a more complete work. But the minute study and thorough investigation of those substances, contained in that fluid, which have not yet been studied, demands so much time, that I did not wish to delay the publication of the results hitherto obtained till the completion of my researches.

Various substances *to be distinguished in the muscular tissue.*

Of the tissue called muscular, fibrine and albumen are the chief constituents in fully-developed animals. This tissue is everywhere interwoven with delicate membranes, and a number of minute vessels are ramified throughout it, which are filled, partly with coloured, partly with colourless fluids. No other part of the body absorbs so large a part of the nervous system. As Berzelius points out, we must distinguish fibrine, albumen, and cellular tissue, partly organised, partly in the state adapted for their conversion into organised structure; and lastly we have, in the fluids, these substances in the effete state, or in the condition best adapted for their removal. We have also to distinguish the coloured and colourless fluids brought to the muscle in the vessels; and the membranes of the distributed nerves as well as the substance itself of those nerves.

Province of chemical analysis.

When analysis shall have become so perfect as to enable us to separate these different substances in a rational manner, she will have fulfilled her duty. At present, analysis begins *by mixing them* altogether, and a chemical result is obtained, which gives room for a multitude of questions. These questions are, in the present state of our knowledge, the conditions of further progress.

Kreatine and kreatinine occur both in muscle and in urine.

Kreatinine and *Kreatine* are constituents of the muscles, but they are also constituents of urine; and if any process in the living body depends upon their presence, it is evident that only that portion of these two compounds can pass into the urine, which has not been employed for vital purposes. *The examination of the urine in diseases will probably* very soon shed light on this question.

Gelatinous matter in the juice of flesh.

That portion of the juice of flesh which is soluble in cold water, but not in alcohol, possesses all the properties of gelatine, except that of gelatinising when concentrated. It is precipitated by tannic acid; the precipitate softens like plaster in hot water, and cannot be distinguished from the tannate of gelatine by its aspect.

Another substance in the juice of flesh.

A second substance, which I have not yet further investigated, separates, during the evaporation of the juice of flesh, in the form of a skin or membrane, which no longer dissolves in cold water, but swells up and becomes mucilaginous. It is not, as might be imagined, caseine.

Unknown nitrogenised bodies in the juice of flesh.

Of the substances soluble in alcohol, the greater part consists of one or probably of more bodies, particularly rich in nitrogen; these are the substances, which, after the phosphoric acid has been removed, give rise, on incineration of the residue, to so great a mass of cyanide of potassium.

New acid in the juice of flesh, not yet studied.

When that part of the juice of flesh which is soluble in alcohol and in ether is mixed with sulphuric acid, to separate the alkali, and the filtered liquid is left at rest for some days, there are deposited long transparent colourless needles, which have a strong acid reaction and contain no alkali. I first noticed this substance at the close of this investigation, and obtained too small a quantity to enable me to analyse it.

Another nitrogenised acid in flesh.

Lastly, if the acid liquid thus obtained be saturated with lime, evaporated to dryness, and the residue washed with alcohol, the addition of ether to the alcohol causes a deposit; and the liquid separated from this contains kreatinine, combined with an organic acid, rich in nitrogen, which I have, in like manner, not yet more minutely examined.

Urea not found in the juice of flesh.

I have taken the utmost pains to detect urea or uric acid in the juice of flesh, and I believe that I should have succeeded in doing so, even had no more than one-millionth part of these substances been present. According to my experiments, therefore, urea is not a constituent of the juice of flesh.

Uric acid supposed to have been found in it on one occasion only.

In one case only where I had added chloride of barium to the alcoholic solution of the extract of flesh, crystalline flocculi separated after exposure for weeks in the air. These were not dissolved by hot water or in hydrochloric acid, but dissolved in nitric acid, with disengagement of red fumes, exactly like uric acid; and the solution gave with ammonia the same purple colour which uric acid would have given in like circumstances. This substance, however, I have not been able again to procure.

ADDENDUM.

NOTE BY THE EDITOR.

From the mother-liquor which had deposited the kreatine which I prepared and which contained the soluble matter of nearly 7 lbs. of fowl, I obtained, by the process indicated at p. 77, by the author, 4 grammes, or about 61 grains of pure and well-crystallised inosinate of baryta. It is certain that I did not succeed in obtaining the whole of the inosinic acid originally present in the juice; but the above quantity was procured without difficulty; and it would therefore appear that in fowl, at least, the quantity of inosinic acid is not so small or insignificant as the author seems to think.

TABLE

SHOWING THE PROPORTION BETWEEN THE ENGLISH AND HESSIAN STANDARD OF WEIGHTS AND MEASURES.

1 lb. English is equal to 0·90719 lbs. Hessian.
1 Hessian acre is equal to 26,910 English square feet.
1 English square foot is equal to 1·4864 Hessian square feet.
1 English cubic foot contains 1·81218 of a Hessian cubic foot.

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