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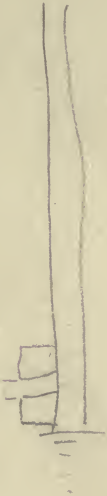

RESEARCHES

ON THE

CHEMISTRY OF FOOD,

AND THE

MOTION OF THE JUICES

IN

THE ANIMAL BODY.

BY

JUSTUS LIEBIG, M.D.,

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BY

JUSTUS LIEBIG, M. D.,
PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF GIESSEN.

EDITED FROM THE MANUSCRIPT OF THE AUTHOR,

BY WILLIAM GREGORY, M. D.,
PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF EDINBURGH.

EDITED FROM THE ENGLISH EDITION,

BY EBEN N. HORSFORD, A. M.,
RUMFORD PROFESSOR IN THE UNIVERSITY AT CAMBRIDGE.

LOWELL: Mass
DANIEL BIXBY AND COMPANY.
1848.

CAMBRIDGE:
METCALF AND COMPANY,
PRINTERS TO THE UNIVERSITY.

PREFACE

TO THE AMERICAN EDITION.

In the following pages, the style is a little more scientific than that of the author's Agricultural Chemistry. It may have been made so, in the knowledge that his previous works have been generally read, and the readers thereby prepared for an additional effort in the perusal of this.

A few changes in terminology from the English edition have been made, not without hesitation, nor yet without consultation.

Hydrosulphuric acid, for *sulphuretted hydrogen*, and *sulphide*, for *sulphuret*, are already elsewhere in use.

The compounds formed by iodine, bromine, and chlorine, when hydroiodic, hydrobromic, and hydrochloric acids are poured into salts of the heavier metals, as silver and lead, are called *iodides*, *bromides*, and *chlorides*. There is no sound reason why this nomenclature should not be extended to the sulphur compounds from hydrosulphuric acid with the same metals.

The word *alkaline* is employed generally among English and American chemists with two entirely distinct significations, —

1st. As qualifying a reaction, and distinguishing it from acid or neutral ; and,

2d. As indicating the base in a salt, implying that it is either potassa, soda, lithia, or ammonia.

The first applies to solutions, not only of alkalies, but of alkaline earths and many of the higher metallic oxides, and certain of the basic and neutral salts.

There is here an obvious deficiency. I venture to suggest the word *alkalic* for the second case, where the adjective refers to a salt of potassa, soda, lithia, or ammonia, retaining the epithet *alkaline* exclusively to qualify the reaction of *any* base or salt which imparts, in solution, a blue tint to reddened litmus, or changes the yellow of curcuma to brown.

This is but adopting the nomenclature of Berzelius, upon which, in fact, nearly all chemists act, in giving the first place to the base in their formulæ of salts.

The confusion which will be avoided by the employment of these two words in their respective places will be appreciated by turning to page 82. What, for example, is "an acid alkaline lactate," or a "neutral alkaline phosphate"?

On the receipt of the first part, "Researches on the Chemistry of Food," there were prepared in the Cambridge Laboratory, from the flesh of wild pigeons (*Columba migratoria*), kreatine, sarcosine, and inosinic acid, in considerable quantities. The lean meat of a hundred and forty pigeons made the quantities sufficiently large to operate upon advantageously. The processes here given are, with the aid of a good press, exceedingly easy to follow.

The second part, which was received from the author by the steamer of the 27th of March, has been translated and edited, as was the first part, by Professor Gregory of the University of Edinburgh.

The importance of the principles established in relation to the transpiration of liquids must impress itself on every one interested (and who is not?) in the preservation of health.

In a letter addressed to the editor, dated Giessen, November 5th, 1847, Professor Liebig, after briefly detailing the course of experiment and general conclusions, says: — "The application of these results to the animal body scarcely requires more detailed explanation. The surface of the body is a membrane from which evaporation goes uninterruptedly forward. In consequence of this evaporation, all the fluids of the body acquire, in obedience to atmospheric pressure, motion towards the evaporating surface. This is obviously the chief cause of the passage of the nutritious fluids from the bloodvessels, and of their diffusion through the body.

"We know now what important functions the skin (and lungs) fulfil through evaporation. It is a condition of nourishment, and the influence of a moist or dry air upon the health of the body, or of mechanical agitation by walking or running, which increases the perspiration, is self-evident."

In view of the results of this investigation, the author remarks, in a letter bearing date January 6th, 1848:—"I consider this investigation the most important I have ever made."

This estimate which Professor Liebig has placed upon his own work will make it not the less acceptable to the physiological public. It will be read with increased interest from the attention which Matteucci's work, and particularly that part of it relating to Endosmosis and Exosmosis, has called to this department of inquiry.

The susceptibility of some persons to changes in the condition of the atmosphere, the value of Franklin's air-bath, the advantages of regular sea or fresh-water bathing, some of the effects of hydropathic treatment, the consequences of drought on vegetation, the renewed greenness and life after a shower, the influence of winds blowing from off a sheet of water, a mountain, or a sand-plain, and many other phenomena hitherto but obscurely understood, all find a more or less perfect explanation in the experimental results recorded in the following pages.

In relation to the potato disease, the views of the author give harmony to a large class of facts upon record, and the method of Dr. Klotzsch, which promises so well, seems a practical application of these views.

It has been stated, that, during the last year or the year previous, several swaths were spread through a potato field while the tops were young and green, and that those hills, the tops of which had been partly removed, contained at harvest time only sound potatoes, while everywhere else throughout the field the tubers were infected by the rot.

A farmer on Long Island caused the blossoms as they appeared in his potato field to be picked off, and found only sound potatoes in the hills at harvest time.

These facts have a new interest and significance from the support which they lend to the views of Baron Liebig and the method of Dr. Klotzsch.

It is to be hoped that this method will meet with a faithful trial.

EBEN N. HORSFORD.

CAMBRIDGE, May 12, 1848.

In relation to the present disease, the causes of [illegible] [illegible] as I have given [illegible] [illegible] and the method of Dr. Hahnemann, [illegible]

It has been already shown that [illegible] [illegible]

[illegible]

[illegible]

[illegible] with a faithful trial.

JOHN N. [illegible]

[illegible], Feb. [illegible]

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RESEARCHES
ON THE
CHEMISTRY OF FOOD.

PREFACE

TO THE ENGLISH EDITION.

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 honored 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 physiologists 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,
31st May, 1847.

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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, 1st June, 1847.

RESEARCHES

ON THE

CHEMISTRY OF FOOD.

SECTION I. — INTRODUCTORY.

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

Animal Chemistry has been in the hands of adventurers.

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.

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. 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.

Pathologists neglect pure chemistry.

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 labors 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.

Varied results of vegetation

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.

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

must depend on similar causes; not yet studied.

There is, probably, no fact more firmly established,

Agency of decomposing

animal compounds.

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.

Agency of ferments compared with that of ordinary affinity.

The transformation caused by a

That the elements of sugar, of sugar of milk, of starch, &c., in contact with the sulphurized and nitrogenized 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, 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 are opposed to those of the acting body, and by which, therefore, its affinity is neutralized. 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.

ferment varies with the state of the ferment.

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 organized 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

These principles are concerned in the vital processes.

The change of matter is

a chief cause of the transformations of the food.

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

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

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 crystallizable 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?

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

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

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

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

least information 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.

Example from the history of Salicine.

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 difficuly. 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.

Erroneous application of this method.

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 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

When we dissolve uric acid in diluted nitric acid, action of nitric acid on uric acid.

carbonic acid and nitrogen gases are given off in equal volumes, and we obtain an acid solution, which, if neutralized 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, representing the decomposition of proteine by alkalies,

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 products 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 proteine 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

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.

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 crystallizable body, Tyrosine (I give this name to 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 coloring 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 analyzed 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 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.

The theory of proteine never expressed 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 sulphurized and nitrogenized 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* sulphurized and nitrogenized 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 these compounds arranged?

The question, in what way the elements of fibrine, albumen, and caseine are arranged, is one of the 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 vapor, 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 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 various proportions of sulphur and phosphorus,

although they were not shown to contain phosphorus.

combined with it; it dissolved in the form of sulphide 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 neutralized 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 sulphide, or of the sulpho-phosphide, 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.

		eq.		eq.		eq.	
Crystalline humor	contains for	15	Proteine	1	Sulphur		
Caseine	"	10	"	1	"		
Vegetable gelatine	"	10	"	2	"		
Albumen of eggs	"	10	"	1	"	& 1	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.

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.*

while fibrine has the same composition as albumen of eggs.

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.

Such views constitute no real progress.

Any one, who will take the trouble to prepare 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.

Sulphur exists in two forms in animal substances;

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.

in the form in which it occurs in cystine

and in taurine.

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 researches.

Larger amount of sulphur present.

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 hydrosulphuric acid 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 oxidized,* 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 wonder-

Proteine cannot be obtained by Mulder's methods.

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

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* See Appendix A.

ful 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 chemists 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 coloring 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 color. 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 there

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* **Handbuch, Vol. IX. p. 573.**

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 precipitated by hydrosulphuric acid, the acid liquid boiled with animal charcoal and evaporated. It leaves a colorless, 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 have endeavoured to prove in a former work to be different from acetic acid, is likewise nothing more than

in 1807,

a similar combination of acetic acid with a peculiar

1823,

animal substance, which accompanies it in its salts, is the cause of the differences between these salts and

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* Jahresbericht, Jahrgang II. p. 72.

the acetates, and moreover prevents the volatilization 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 neutralized with caustic ammonia and heated, yields distinctly vapors of acetate of ammonia, becoming acid at the same time."

In the seventh yearly volume of his Jahresbericht, 1828, 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 impure 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 sulphovinates or nitroleucates sulphates or nitrates."

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: — and 1832.

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* Annalen der Pharmacie, Vol. I. p. 1. 1832.

"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 no longer sufficient,

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 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-nitrogenized 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 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 κρέας, 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 colors; 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,

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* See Annalen der Chemie und Pharmacie, Vol. LXI. p. 216.

and deposits small granular crystals. Kreatine dissolves in hydrochloric acid: the solution gives, on evaporation, colorless dendritic crystals, which do not precipitate bichloride of platinum.

"In its aqueous solution, kreatine is spontaneously although slowly decomposed, there is observed a distinct odor 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 colored, 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 vapor, 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 crystallization, which is expelled by a heat of 212°; its ultimate elements are carbon, hydrogen, nitrogen, and oxygen, in proportions not yet ascertained." (Journal dè 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

His opinion.

have had an opportunity of seeing kreatine in the possession of that distinguished chemist. It would appear, therefore, rather to be an accidental ingredient, the presence of which depends on peculiar circumstances 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."

Wöhler obtains it. It is not allantoine.

Schlossberger finds it in the flesh of the alligator.

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 odor of roast meat, such as is understood under the term Osmazome, as obtained from ordinary flesh. Hot alcohol dissolved a considerable part with a yellow color, and deposited, on cooling, small cubical yellowish crystals, which may be washed with water, or better with alcohol. Thus purified, they had all the characters of Chevreul's kreatine. When heated, they become white and opaque, then melt, giving out a yellow vapor and an ammoniacal empyreumatic odor, 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 color, soon passing into brown. They dissolved in strong nitric acid with the evolution of yellow vapors, and the solution, when evaporated, left a white residue. The aqueous solution of the crystals is not precipitated by

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[*] Annalen der Chemie und Pharmacie, Vol. XLIX. p. 343.

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 crystallize 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."

Schlossberger's opinion.

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 crystallizing, 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-nitrogenized 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, to be described in the following pages in the order in which they present themselves to the observer.

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

Flesh extracted by water.

When the finely minced flesh of newly-killed animals is extracted by water, there is obtained a red or reddish-colored 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 color. The albumen at first separates as a nearly colorless coagulum, which afterwards collects in denser flocculent masses, and the coloring 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 coloring 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 coloring matter in the coagulated state, and we thus obtain a liquid easily filtered, which reddens litmus powerfully. The coagulated albumen, together with the undissolved fibrine and cellular tissue, has 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-

Albumen and coloring matter coagulated by heat.

The filtered liquid is acid.

white, of horny hardness, and the water acquires by dissolving gelatine the property of gelatinizing on cooling, when sufficiently concentrated.

A good press is indispensable.

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 coloring 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.)

Small proportion of soluble matter in flesh.

8 or 10 lbs. of flesh should be used.

Best mode of extraction.

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 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 coloring 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 color, and the whole of the albumen and coloring 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 coloring 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 coloring matter, is strained through a cloth, the coagulum pressed, and the united liquids filtered.

The color 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 color; while that from veal and fowl, as well as that from fish, is hardly colored.

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 neutralize 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 color, 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 color 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 color 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

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.

by the addition of baryta.

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.

Phosphates are precipitated.

No ammonia is disengaged,

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.

and no sulphates are found in the precipitate.

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

The filtered liquid must be gently evaporated.

liquid, dissolves in it without perceptibly coloring it; but in this case the color comes out when the liquid is concentrated. When the liquid from fowl's 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.

A skin formed in some cases during evaporation.

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.

The concentrated liquid deposits kreatine in crystals.

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, colorless needles appear on the surface, which increase on standing, and on cooling, so that the walls of the vessel are gradually covered with them.

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.

Modification of the process for fish.

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 colorless, slightly opalescent, has an 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 colorless 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 kreatine obtained by the author.

From 100 lbs. (Hessian) of the flesh of an old, 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 found in the brain, liver, or kidneys, but the heart contains it.

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

Peculiarities worthy of investigation in the brain and liver.

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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.

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.

Kreatine.

Purification of 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 colored, some animal charcoal (from blood) is added, and a very small quantity is sufficient to give a liquid which, when filtered, is colorless and limpid, and which, on cooling, deposits the kreatine in perfectly pure crystals.

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 recrystallization; 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 colorless, 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 crystallized kreatine lost, at 212°, 0.059 gramme of water = 12.16 per cent.

0.3582 gm. of crystallized kreatine lost, at 212°, 0.044 gm. of water = 12.28 per cent.

0.5835 gm. of crystallized kreatine lost, at 212°, 0.0705 gm. of water = 12.08 per cent.

0.603 gm. of crystallized 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 crystallization.

The combustion of dried as well as of crystallized 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 crystallized creatine yielded 0.6764 gm. of carbonic acid. (The water was lost in this analysis.)

0.5830 gm. of crystallized kreatine yielded 0.693 gm. of carbonic acid, and 0.388 gm. of water.

0.545 gm. of crystallized kreatine yielded 0.658 gm. of carbonic acid, and 0.367 gm. of water.

0.2884 gm. of crystallized 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 2d tube gave for 89 vol. nitrogen 217 vol. carbonic acid.

3d	“	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

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 crystallized 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 crystallized 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

Kreatine and glycocoll.

If we compare the formula of kreatine with that of

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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.

glycocoll (sugar of gelatine), it appears that crystallized kreatine contains the elements of

$$\begin{array}{rl} \text{2 eqs. glycocoll} = & C_8\,N_2\,H_8\,O_6 \\ +\,\text{1 eq. ammonia} = & \underline{\quad N\;\;H_3\quad} \\ & C_8\,N_3\,H_{11}\,O_6\;{}^* \end{array}$$

Properties of kreatine.

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 crys-

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* Kreatine contains the elements of the Lactamide of Pelouze, and Urea, as Liebig has suggested in a letter to Gay-Lussac, which was published in the "Comptes Rendus" of last year.

Kreatine. *Lactamide.* *Urea.*

$$C_8\,H_{11}\,N_3\,O_6 = C_6\,H_7\,N\,O_4 + C_2\,H_4\,N_2\,O_2.$$

Lactamide is lactic acid or lactic sugar in which one atom of oxygen has been replaced by an atom of amidogen.

Lactic acid. *Lactamide.*

$$C_6\,H_5\,O_5 - O + N\,H_2 = C_6\,H_7\,N\,O_4.$$

Lactamide contains the elements of glycocoll and oxide of methyle.

Lactamide. *Glycocoll.* *Oxide of Methyle.*

$$C_6\,H_7\,N\,O_4 = C_4\,H_4\,N\,O_3 + C_2\,H_3\,O.$$

Glycocoll has been resolved by a current of electricity into ammonia and aconitic acid (?).

Glycocoll. *Ammonia.* *Aconitic Acid.*

$$C_4\,H_4\,N\,O_3 = N\,H_3 + C_4\,H\,O_3.$$

Kreatine may be considered as having the elements of urea, oxide of methyle, aconitic acid, and ammonia.

Kreatine. *Urea.* *Oxide of Methyle.* *Aconitic Acid.* *Ammonia.*

$$C_8\,H_{11}\,N_3\,O_6 = C_2\,H_4\,N_2\,O_2 + C_2\,H_3\,O + C_4\,H\,O_3 + N\,H_3.$$

Urea with two atoms of water contains the elements of carbonic acid and ammonia.

Urea.

$$C_2\,H_4\,N_2\,O_2 + 2\,H\,O = 2\,C\,O_2 + 2\,N\,H_3.$$

These relations are interesting to contemplate, when we recollect that kreatine, milk sugar, urea, carbonic acid, ammonia, and glycocoll, as a benzoate in the form of hippuric acid, are found in the liquid excrements of man.—E. N. H.

tallizes 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.

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.

Kreatine is neither acid nor basic.

No quantity, however large, of kreatine can destroy the acid reaction even of the weakest acids; it possesses no basic characters. It dissolves easily with the aid of heat in barytic water, and crystallizes 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 color 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 color 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 crystallized 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 di-

Purification of kreatinine.

luted, 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.

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 $\infty P \infty$. The orthodiagonal is less than the klinodiagonal. The angle $o P : \infty P \infty$, 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 $\infty P \infty$ forms with $\infty P = 130° 50'$.*

Kreatinine is much more soluble in cold water than kreatine. 1,000 parts of water dissolve 87 parts of

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

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 crystallizes 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 crystallize 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 colorless needles.

on chloride of zinc,

In a neutral aqueous solution of chloride of zinc, 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 crystallizable double salts of a fine blue color.

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 crystallized 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 crystallized 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.		CO_2.
* The 2d tube	yielded	75	for	187
3d	"	77	"	197
4th	"	79	"	207
5th	"	48	"	126
6th	"	70	"	200
7th	"	85	"	215
$N : CO_2 = 3 : 8$		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 analyzed 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 neutralized with carbonate of soda, evaporated till the salts crystallize 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 crystallizable 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, sul-

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* Annalen der Chemie und Pharmacie, Vol. LII. p. 97.

phuric 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 neutralized 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 crystallize 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 crystallized 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 coloring 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 crystallization, of different form and properties, is obtained. The body which crystallizes first, or remains in the undissolved residue, contains water of crystallization and has no action on vegetable colors; 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, that the one which first crystallized 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.*

Analysis of the compounds from urine.

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 car-

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

bonic 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.

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 sep-

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*		N.		CO_2.
The 2d tube yielded		52	for	142
3d	"	71	"	189
4th	"	69	"	183
5th	"	88	"	226
		280	"	740

arates 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 coloring 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 neutralized 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 kreatinine; 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 crystallizes from it in short, transparent, colorless 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.

When to a boiling saturated solution of kreatine we add ten times the weight of the kreatine of crystallized 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 colorless 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

Sarcosine.

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, colorless, 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 crystallizes 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 $\infty p : \overline{P} \infty$. 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 colorless, 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.

Formula of sarcosine.

This gives for 100 parts,

		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

	N.	C O².
* The 2d tube yielded	42	233
3d "	38	241
4th "	40	230
5th "	40	243
6th "	43	252
	203	1,199

Properties of sarcosine.

The aqueous solution of sarcosine has no action on vegetable colors; 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 color as is caused by ammonia, and by gentle evaporation there are obtained thin scales of the same color.

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 color, 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 . .	89.0	196.2	66.55	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 crystallized 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. 57). 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 colorless 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 crystallize 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 crystallized salt at 212° indicates the presence of 1 eq. of water of crystallization = 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

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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.

I regret much that want of material prevented me from multiplying experiments with this interesting 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 crystallized 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 of urea. If the alcoholic solution be heated with oxide of lead, nitrate of lead is precipitated, and the liquid gives, on evaporation, colorless 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,

Urea is formed in the process.

is dissipated in the form of the vapor 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 crystallized, and the liquid neutralized 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 crystallize, long colorless 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 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.

Another substance occurs; 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

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* See note on p. 42.

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 recrystallization, 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 colorless 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 crystallization. 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 vols. 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.

Hence, the anhydrous inosinate of baryta contains

	N.	CO_2
* The 2d tube yielded	49	235
3d "	45	245
4th "	42.5	193.5
	136.5	673.5

$N : CO_2 = 1 : 5.$

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	30.49
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, causes 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. 64). It is very soluble in water, and crystallizes 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

Formula of the anhydrous salt.

			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

The loss of weight at 212° indicates the presence of 7 eqs. of water of crystallization = 22.5 per cent.

Inosinate of soda.

Inosinate of Soda. — This salt crystallizes 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 crystallized 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.

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 color in ammonia.

Inosinate of silver.

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.

The inosinate of silver obtained in the analysis of the potash salt (see p. 67) was decomposed by hydrosulphuric acid, and the sulphide 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 color 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 colorless 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 preparation of inosinates from the juice of flesh.

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°.

Kreatinine, as a Constituent of Muscle.

Kreatinine exists in the juice of flesh.

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 color, amounting to $\frac{1}{20}$th 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.

Its extraction.

In the heavy viscid portion, at a temperature of 23°, there are soon formed a number of transparent colorless 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.

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 colorless; 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 percentage 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.

Analysis of kreatinine from the juice of flesh.

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.

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 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 neutralized 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 prep-

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*	N.	CO_2.
The 2d tube yielded	60	156
3d "	66	176
4th "	79	211
	205	543

N : C = 3 : 8.

aration. 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 nitrogenized acid, differing in properties from inosinic acid; they are contained in the mother liquid, the chief ingredient of which is uncrystallizable 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 colorless, 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 colored, 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 crystallizes. 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.

Analysis of the lactates prepared from flesh.

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.

Lactate of lime.

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

Hence, lactate of lime contains, in 100 parts,

Formula of the anhydrous

	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

The crystallized lactate of lime contains

and of the crystallized salt.

	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. crystallized Lactate of lime	145	100.00	100.0	100.0

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 analyzed.

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 crystallized 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 in the crystals;

Hence, the crystallized lactate of zinc contains *

		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. crystallized Lactate of zinc	139.5	100.00	100.00

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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 crystallization. It is possible that this variation in the

The ultimate analysis of the anhydrous lactate of zinc gives

in the anhydrous state.

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

From the preceding analysis it evidently appears that the non-nitrogenized 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 non-azotized acid of flesh is lactic acid.

The Inorganic Constituents of the Juices 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 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.

Inorganic constituents of the juice of flesh.

It is evident that alkalic salts are the preponderating inorganic constituents of the juice of flesh, and

Alkalic salts preponderate in it.

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amount of water in these two salts depends on this, that the lactates from flesh were crystallized 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.

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 alkalic 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 organized constituents of the body have been derived from unorganized matters, and return to the unorganized state; and it is especially with the unorganized 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 alkalic 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 color, 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. Meta-

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* The following formulæ will serve to elucidate the above reactions.

$3\ Meo, P\ O_5$ is the neutral tribasic phosphate.

The atoms of base may be all of metallic oxide, as

(*a*) $3\ Ca\ O, P\ O_5,$ $3\ Mg\ O, P\ O_5,$ or $3\ Na\ O, P\ O_5,$ or two of metallic oxide and one of water or ammonia,

(*b*) $2\ Na\ O, H\ O, P\ O_5,$ or $2\ Mg\ O, N\ H\ O_4,$ $P\ O_5,$ or one of fixed base, one of ammonia, and one of water, as

(*c*) $Na\ O, N\ H_4\ O, H\ O, P\ O_5.$

If (*a*) be ignited, it remains unchanged.

If (*b*) be ignited, the water or ammonia is driven out, and $2\ Na\ O, P\ O_5,$ or $2\ Mg\ O, P\ O_5,$ the bibasic phosphate or pyrophosphate, remains.

If (*c*) be ignited, both ammonia and water are driven out, and the $Na\ O, P\ O_5,$ metaphosphate or monobasic phosphate, remains.

(*a*) gives a strong alkaline reaction, a yellow precipitate with nitrate of silver, and a neutral filtrate.

$$3\ Ca\ O, P\ O_5 + 3\ [Ag\ O, N\ O_5] = 3\ Ag\ O, P\ O_5 + 3\ [Ca\ O, N\ O_5].$$

(*b*) gives an alkaline reaction, a yellow precipitate with nitrate of silver, and an acid filtrate.

$$2\ Na\ O, H\ O, P\ O_5 + 3\ [Ag\ O, N\ O_5] = 3\ Ag\ O, P\ O_5 + 2\ [Na\ O, N\ O_5] + H\ O, N\ O_5.$$

After ignition the reaction is alkaline, the precipitate with nitrate of silver white, and the filtrate reacts neutral.

$$2\ Na\ O, P\ O_5 + 2\ [Ag\ O, N\ O_5] = 2\ Ag\ O - P\ O_5 + 2\ [Na\ O, N\ O_5.]$$

(*c*) gives an acid reaction, a yellow precipitate with nitrate of silver, and an acid filtrate.

$$Na\ O, N\ H_4\ O, H\ O, P\ O_5 + 3\ [Ag\ O, N\ O_5] = 3\ Ag\ O, P\ O_5 + Na\ O, N\ O_5 + N\ H_4\ O, N\ O_5 + H\ O, N\ O_5.$$

After ignition, the salt gives a white precipitate with silver salt.

$$Na\ O, P\ O_5 + Ag\ O, N\ O_5 = Ag\ O, P\ O_5 + Na\ O, N\ O_5.$$

—E. N. H.

phosphate 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 colors of the precipitate are constantly observed.

The ashes of the juice of fowl contain pyrophosphates and metaphosphates.

The ashes of the juice of the flesh of fowl give a different result. The aqueous solution precipitates nitrate of silver purely white; the ashes, therefore, contain alkalic 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. From this it follows, that the juice of the flesh of fowl must contain a certain though small quantity of alkalic 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 neutralize 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 acid. 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 alkalic lactate and acid alkalic phosphate (phosphate with one atom of alkali); or, in other words, of neutral alkalic lactate and phosphate, along with free lactic and phosphoric acids.

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

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.

Equilibrium between these free acids.

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.

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 alkalic 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 neutralize 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 neutralized 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 lactate of zinc. All the urine for the two subsequent hours was collected. In each case the urine, before the experiment, had an acid re-

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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.

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

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

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

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 favorable to the production of an electrical current, and it is far from improbable that such a current takes a certain share in the

The conditions of an electrical current are present.

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 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, were 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 pecu-

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* Professor H. Buff has, at my request, constructed a pile, consisting of disks 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.

liar 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 acid is abundantly disengaged. If bichloride of platinum be now added, to separate the potash from the soda, the precipitate which is formed contains ammonium-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 Fowl, 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. 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,

			Potash in the Blood.	Potash in the Flesh.
For 100 parts of soda in the		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, justify the assumption that both facts are altogether indispensable for the processes carried on in the blood and in the fluid of the muscles.

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 dis-

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* Schmidt, Annalen der Chemie und Pharmacie, Vol. LXI. p. 329.

tance 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

Action of phosphate of potash on chloride of sodium.

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 crystallizable, and has a very feeble *alkaline* reaction.

When we supersaturate phosphoric acid (tribasic) with potash, and evaporate to crystallization, 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 neutralized with potash, and chloride of sodium added to the solution, and the whole left to spontaneous evaporation, a phosphate crystallizes, 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.*

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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.

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 decomposition 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. ($\frac{1}{3}$d 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 $\frac{1}{3}$d of the whole carbonate of soda contained in that volume of blood. When concentrated to $\frac{1}{3}$d by evaporation, this liquid must contain exactly as much, if concentrated to $\frac{1}{6}$th, twice as much, to $\frac{1}{12}$th, four times as much, and to $\frac{1}{24}$th, 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 $\frac{1}{500}$th 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

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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.

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 $\frac{1}{3}$d 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.

7.5 cubic inches of serum cannot contain more than 2-5ths of a grain of carbonate of soda,

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 favorable 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 $\frac{1}{166}$th part of the volume of the serum. This amounts, for 1000 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 $\frac{2}{5}$ths 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 ?*

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 NaO, HO), 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.†

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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 two atoms of fixed base (PO_5, 2 NaO, HO).

† A solution of phosphate of soda, saturated with carbonic

By simple agitation with air, or by diminution of the atmospheric pressure, ⅔ds of the absorbed carbonic acid are given off at the ordinary temperature; by contact with fresh carbonic acid, these ⅔ds are immediately again absorbed.*

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acid, may be recommended as one of the pleasantest saline purgatives.

Experiments. * A solution of 1 part of dry phosphate of soda, $PO_5, 2NaO, HO$, 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.

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 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 favorable 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

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

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.

Influence of acids, alkalies, and salts on respiration.

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.

The juice of flesh contains very little lime.

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 millegrammes (1 millegramme $=\frac{1}{75}$th 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.

Proportion of lime to magnesia in the juice of fowl.

The juice of fowl's flesh was precipitated by 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 $P\ O_5,\ 3\ Ba\ O$), partly with magnesia (as $P\ O_5,\ 3\ Mg\ O$). 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.

Boiled meat without the soup is not nutritious.

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.

Cold water extracts all the soluble constituents of flesh.

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

Importance of their constituents.

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 color.* 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 flavor 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

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

depends on the soluble matter.

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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 flavor, 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 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.

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

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

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.

The flesh of old animals contains little albumen, but much fibrine.

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

Muscular fibre.

Its tenderness depends on the albumen of the juice.

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 coloring 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 colors which they present. At all those parts which appear bloody, the temperature has not reached 144°.

Poultry is sooner done than beef or mutton.

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.

Use of a covering of lard in roasting.

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, is kept in the tender state which is otherwise only found in the inner portions of large masses of flesh.

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 unfavorable 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, is 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 or flavor of soup.

It has long been customary to ascribe to the gelatinous matter dissolved during boiling, which gives to concentrated soup the property of forming 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 favorable 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 gelatinized when reduced to half, that from beef when reduced to $\frac{1}{16}$th, 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 favorable 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		
	1000		

It follows, that boiling water, when allowed to act for five hours on finely chopped flesh, 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 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 flavored 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

The influence which the brown color of this soup, color of soup on the judgment we form as to its strength and flavor.

or color in general, exercises on the taste, in consequence of the ideas associated with color in the mind (ideas of strength, concentration, &c.), may be rendered quite evident by the following experiment. The soup, colored brown by means of caramel, is declared by all persons to have a much stronger taste than the same soup when not colored; 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 color and a delicate flavor 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-flavored 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 1-32d 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

Extract of meat recommended as a restorative for wounded soldiers.

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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 flavor of soup, and probably, therefore, contained a certain proportion of extract of flesh. — W. G.

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.

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 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, furnishes 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 ⅓d of the fluid contained in the raw flesh.

The brine of salt meat contains the

I have ascertained that this brine contains the chief constituents of a concentrated soup or infusion of meat,

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* See Proust, Annales de Chimie et de Physique. Third Series, Vol. XVIII. p. 177.

ingredients of the extract;

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 neutralized by lime, gives, after the salt has been crystallized 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.

Salted meat is deficient in nutritive quality.

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 pre-

Causes of this.

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

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

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 crystallized 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 crystallization. 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 crystallization, 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 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. 109), may perhaps admit 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.

The gastric juice similar to the juice of flesh.

The soup 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 volatilized, 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 circum-

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

stances, 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.

CONCLUSION.

These researches only the commencement of a more complete investigation.

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 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, demand 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 colored, partly with colorless 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 organized, partly in the state adapted for their conversion into organized 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 colored and colorless 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 gelatinizing 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 nitrogenized 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 colorless 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 analyze it.

Another nitrogenized 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.

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

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. 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 color 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. 63, by the author, 4 grammes, or about 61 grains, of pure and well-crystallized 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 lb. 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 Hessian cubic feet.

RESEARCHES

ON THE

MOTION OF THE JUICES

IN

THE ANIMAL BODY.

PREFACE

TO THE ENGLISH EDITION.

In the Editor's Preface to Baron Liebig's "Researches on the Chemistry of Food," in which the author gave the results of his investigation into the constituents of the juice of flesh, I mentioned that Baron Liebig had been led to study the subject of Endosmosis experimentally. The results of this investigation are contained in the following pages; and the reader will, I trust, be satisfied that the motions of the animal juices depend on something more than mere Endosmosis or Exosmosis, and that the pressure of the atmosphere, as well as its hygrometric state, by influencing the transpiration from the skin and lungs, is essentially concerned in producing these motions. At the same time, the present work is to be regarded, not as exhausting the subject, but, on the contrary, as only pointing out the direction in which inquiry is likely to lead to the most valuable results.

While it is proved that the mechanical causes of pressure and evaporation, and the chemical composition of the fluids and membranes, have a more direct, constant, and essential influence on the motion of the animal fluids, and consequently on the state of the health, than has been usually supposed, it is evident that very much remains to be done in tracing that influence under the ever varying circumstances of the animal body, and in applying the knowledge thus acquired to the purposes of hygiene and therapeutics. But it is equally obvious, that the above-mentioned mechanical and chemical causes are not alone sufficient to explain the phenomena of animal life, since they are present equally in a dead and in a living body; so that while every advance in physiology enables us to explain more facts on chemical and mechanical principles, something always remains, which, for the present, is beyond our reach, and which may for ever remain so. However this may be, the facts established in this and in the preceding work of the author have very materially extended the application of the well-known laws of physics and of chemistry to physiology, and have also furnished a number of the most beautiful instances of that infinitely wise, but exquisitely simple, adaptation of means to ends which characterizes all the works of the omnipotent Creator; but which is nowhere more admirably displayed than in the arrangements, imperfectly known as they hitherto have been, by which life is maintained.

In connection with the author's remarks on the effects of evaporation in plants, and the consequences of its suppression, and with his opinions as to the origin of the potato disease, I beg to refer the reader to the Appendix for a very ingenious and apparently well-founded plan for the protection of the potato-plant against the terrible scourge under which it has lately suffered. The views of Dr. Klotzsch, the author of this plan, as to the nature of the disease, coincide remarkably with those of Baron Liebig, as explained in the present work.

WILLIAM GREGORY.

EDINBURGH, 3d March, 1848.

PREFACE.

The present little work contains a series of experiments, the object of which is to ascertain the law according to which the mixture of two liquids, separated by a membrane, takes place. The reader will, I trust, perceive in these researches an effort to attain, experimentally, to a more exact expression of the conditions under which the apparatus of the circulation acquires all the properties of an apparatus of absorption.

In the course of this investigation, the more intimate study of the phenomena of Endosmosis impressed on me the conviction, that, in the organism of many classes of animals, causes of the motion of the juices were in operation far more powerful than that to which the name of Endosmosis has been given.

The passage of the digested food through the membranes of the intestinal canal, and its entrance into the blood; the passage of the nutrient fluid outwards from the bloodvessels, and its motion towards the parts where its constituents acquire vital properties, — these two fundamental phenomena of organic life cannot be explained by a simple law of mixture.

The experiments described in the following pages will, perhaps, be found to justify the conviction, that these organic movements depend on transpiration and atmospheric pressure.

The importance of transpiration for the normal vital process has indeed been acknowledged by physicians ever since medicine had an existence; but the law of the dependence of the state of health on the quality of the atmosphere, on its barometric pressure, and its hygrometric condition, has been hitherto but little investigated.

By the researches contained in my examination of the constituents of the juice of flesh, as well as by those described in the present work, the completion of the second part of my Animal Chemistry has been delayed; but I did not consider myself justified in continuing that work until I had examined the questions suggested by and connected with those researches.

DR. JUSTUS LIEBIG.

GIESSEN, February, 1848.

ON THE PHENOMENA

ACCOMPANYING

THE MIXTURE OF TWO LIQUIDS

SEPARATED BY A MEMBRANE.

The food becomes soluble, and in the fluids of the body is sent to all parts.

The constituents of the food, which have assumed a soluble form in the alimentary canal, are thereby endowed with the property of yielding to the influence of every cause, which, in acting on them, tends to change their place or the position which they occupy. They are conveyed into the bloodvessels, and thence are distributed to all parts of the body.

General causes of their motion.

The movement and distribution of these fluids, and of all the substances dissolved in them, exclusive of the mechanical cause of the contraction of the heart, by which the circulation of the blood is effected, depend, — 1. on the permeability of the walls of all vessels to these fluids; 2. on the pressure of the atmosphere; and 3. on the chemical attraction which the various fluids of the body exert on each other. The motion of all fluids in the body is effected by means of water; and all parts of the animal system contain, in the normal state, a certain amount of water.

Presence of water in all membranes.

Animal membranes, tendons, muscular fibres, cartilaginous ligaments, the yellow ligaments of the vertebral column, the cornea, transparent and opaque, &c., all contain, in the fresh state, more than half their weight of water, which they lose, more or less completely, in dry air.

On the presence of this water depend several of their physical properties. The fresh, opaque, milk-white cartilages of the ear become, when dried, translucent, and acquire a reddish-yellow color. Tendons, when fresh, are in a high degree flexible and elastic, and possess a silky lustre, which they lose when dried. By the same loss of water they become, further, hard, horny, and translucent, and when bent, split into whitish bundles of fibres. The sclerotic coat is milk-white when fresh, and becomes transparent by desiccation.

When these substances, after having lost, by drying, a part of the properties which they possess in the fresh state, are again placed in contact with pure water, they take up, in 24 hours, the whole original amount of water, and recover perfectly those properties which they had lost. The opaque cornea, or sclerotic coat, which had become transparent by desiccation, again becomes milk-white, while the transparent cornea, which had been rendered opaque by drying, now becomes again transparent. The tendons, which, when dried, had become horny, hard, and translucent, now again become flexible and elastic, and recover their silky lustre. The fibrine and the cartilages of the ear, which desiccation had rendered horny and transparent, again become milk-white and elastic.

The tissues absorb other fluids.

The power which the solids of the animal body possess of taking up water into their substance, and of being penetrable to water, extends to all fluids allied to water, that is, miscible with it. In the dried state, the animal solids take up fluids of the most diverse natures, such as fatty and volatile oils, ether, bisulphuret of carbon, &c. This permeability to fluids is possessed by animal tissues in common with all porous bodies; and no doubt can be entertained that this property is determined by the same cause which produces the ascent of fluids in narrow tubes, or in the pores of a sponge, — phenomena which we are accustomed to include under the name of capillary action.

The moistening of porous bodies

One condition, essential to the permeability of porous bodies for fluids (or their power of absorption), is their capability of being moistened, or the attraction which the particles of the fluid and the walls of the pores or tubes have towards each other. A second condition is the attraction which one particle of the fluid has to another. We have no means of estimating the absolute size of the particles or molecules of a fluid, such as water, but they are certainly infinitely smaller than the measurable diameter of a tube or of the pores of a porous body. It is obvious, therefore, that in the interior of a capillary tube or pore, filled with a fluid, only a certain number of the fluid molecules are in contact with the walls of the tube, and attracted by them; while in the middle of the tube, and thence towards its parietes, fluid molecules must exist which only retain their place in virtue of the attraction which the molecules attracted by the parietes exert on those not so attracted, that is, by the cohesive attraction of the fluid.

Liquids flow out of capillary tubes, which are filled with them, only when some other force or cause acts, because capillary attraction cannot produce motion beyond the limits of the solid body which determines the capillary action.

depends on capillary attraction.

The penetration of a fluid into the pores of a porous body is the result of capillary attraction; its expulsion can be effected by a mechanical pressure, and may be accelerated by increasing this pressure, and by all such causes as diminish the mutual attraction of the fluid molecules or the attraction of the walls of the pores for these molecules. The condition most favorable to the passage of a fluid through the pores of a porous substance under pressure is when one fluid molecule can be displaced so as to glide away over another.

Prodigious force with which porous bodies absorb water.

The slightest pressure suffices to expel the displaceable particles of water from a sponge; a higher pressure is required to express the same fluid from bibulous paper; and a pressure much higher still is necessary in order to cause water to flow out of moist wood. We may form some idea of the force with which porous organic substances, such as dry wood, absorb and retain water, if we remember, that, by inserting wedges of dry wood in proper cuts, and subsequently moistening them, rocks may be split and fractured.

Animal tissues are porous.

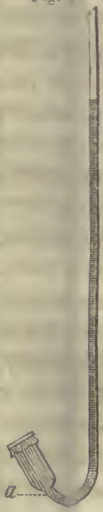
When we compare with the properties just enumerated, which belong to all porous bodies, those properties which are observed in animal substances under the same circumstances, it appears plainly that these animal substances have pores in certain directions, although these openings are so minute that they are not, in the case of most tissues, perceptible even with the aid of the best microscopes.

Amount of water expelled by pressure from the tissues.

It has been mentioned that tendons, ligaments, cartilages, &c., contain, in the fresh state, a certain amount of water, which, according to all experiments made on the subject, is invariable; and that several of the properties depend on the presence of this water. (Chevreul.) When these substances, wrapped in bibulous paper, are subjected to a powerful pressure, a certain proportion of this water is expelled. Fresh and flexible vessels lose in this way 37.6 per cent., and the yellow ligaments of the vertebræ lose 35 per cent. of water. This property, namely, that of losing water under pressure, is only found in porous substances. It is obvious that by pressure, that is, by diminution of the size of the pores, only that portion of water can be pressed out which is not retained by chemical attraction. It is in the highest degree worthy of notice, that this water, not chemically combined, seems to have the greatest share in the properties which these animal substances possess in the fresh state, for the pressed tendons and yellow ligaments become transparent; the former lose their flexibility, the latter their elasticity, and if laid in water, they recover these properties perfectly. In the pores of a porous substance, the fluid molecules are retained by two kinds of attraction, namely, by the affinity which is exerted between the walls of the pores and the molecules of the fluid, and by the cohesion which acts between the molecules of the fluid itself. It would appear as if the molecules of water were thus brought into different states, and this seems to be the cause of the differences observed in the properties of these animal substances when they contain different proportions of water.

The proportion of water not chemically combined has the greatest share in the properties of the tissues.

Fig. 1



Pressure required to force water and other liquids to pass through membranes.

If the wide opening of the tube, Fig. 1, be tied over with a portion of bladder, and water poured into the wide part of the tube so far as the mark *a*, we shall find that, when mercury is poured into the upright narrow part of the tube to a certain height, the whole external surface of the bladder becomes covered with minute drops, which, if the column of mercury be made a few lines higher, unite so as to form large drops. These continue to flow out uninterruptedly, if mercury be added so as to keep the column at the same height, till at last the wide part of the tube is emptied of water and filled with mercury.

Solution of salt, fat oil, alcohol, &c., behave exactly as water does; under a certain pressure these fluids pass through an animal membrane, just as water does through a paper filter.

The pressure required to cause these liquids to flow through the pores of animal textures depends on the thickness of the membrane, as well as on the chemical nature of the different liquids.

The pressure varies with different liquids.

Through ox-bladder, $\frac{1}{10}$th of a line ($\frac{1}{120}$th of an inch) thick, water flows under a pressure of 12 inches of mercury; a saturated solution of sea salt requires from 18 to 20 inches; and oil (marrow oil) only flows out under a pressure of 34 inches of mercury.

When the membrane used is the peritoneum of the ox, $\frac{1}{20}$th of a line ($\frac{1}{240}$th of an inch) in thickness, water is forced through it by 8 to 10 inches, brine by 12 to 16 inches, oil by 22 to 24 inches, and alcohol by 36 to 40 inches of mercury.

The same membrane from the calf, $\frac{1}{166}$th of a line ($\frac{1}{1992}$d of an inch) in thickness, allows water to pass through under the pressure of a column of water 4 inches high; brine passes under a pressure of 8 to 10 inches of brine, and oil under a pressure of 3 inches of mercury.

In making experiments of this nature, we observe, that, after they have continued for some time, the pressure required to force the liquid through the membrane does not continue equal. If, during the first 6 hours, a pressure of 12 inches of mercury were necessary, we often find that, after 24 or 36 hours, 8 or even 6 inches will suffice to produce the same effect, obviously because, by long-continued contact with water, the membrane undergoes an alteration, in consequence of which the pores are widened.

From these experiments it appears that the power of a liquid to filter through an animal membrane bears no relation to the mobility of its particles; for under a pressure which causes water, brine, or oil to pass through, the far more mobile alcohol does not pass.

The absorbent power of the membrane has a share in the effect.

The capacity of the animal membrane for being moistened by, and its power of absorbing, the liquid, have a certain share in producing the result of its filtration through the membrane.

The following table will show this fact: —

100 parts, by weight, of dry ox-bladder, take up, in 24 hours, —

Absorption of different liquids.

of pure water	268	volumes.
“ saturated solution of sea salt (brine)	133	“
“ alcohol of 84 per cent.	38	“
“ oil of marrow	17	“

100 parts, by weight, of ox-bladder, take up, in 48 hours, —

of pure water	310	parts by weight.
“ a mixture of ⅓ water and ⅔ brine	219	“
“ “ ½ “ ½ brine	235	“
“ “ ⅔ “ ⅓ “	288	“
“ “ ½ alcohol ½ water	60	“
“ “ ⅓ “ ⅔ “	181	“
“ “ ¼ “ ¾ “	290	“

100 parts of dry pig's bladder take up, in 24 hours, —

of pure water	356	volumes.
“ brine	159	“
“ oil of marrow	14	“

From these experiments it appears that the absorptive power of animal membranes for different liquids is very different. Of all liquids, pure water is taken up in the largest quantity; and the absorptive power for solution of salt diminishes in a certain ratio as the proportion of salt increases. A similar relation holds between the membranes and alcohol; for a mixture of alcohol and water is taken up more abundantly the less alcohol it contains.*

Action of alcohol and oil when the membranes are dry.

Animal membranes do not acquire, by absorbing alcohol or oil, those properties which they exhibit when saturated with water. A dried bladder continues hard and brittle in alcohol and oil; its flexibility is in no degree increased by absorbing these liquids. When tendons, ligaments (Chevreul), the yellow ligaments of the spine or bladder, saturated with oil, are placed in water, the oil is completely expelled, and they take up as much water as if they had not previously been in contact with oil.

Action when in moist condition.

It has been mentioned, that 100 parts of animal membrane (dry ox-bladder) absorb, in 24 hours, 268, in 48 hours, 310 volumes of water, and only 133 of saturated solution of salt. It follows, of course, that when the bladder, saturated with water by 48 hours' contact, and well dried in bibulous paper, without pressure, to remove superfluous water, is strewed with salt, there is formed, at all points where salt comes in contact with the water, filling the open pores, a saturated solution of salt, the salt contained in which diffuses itself equally in the water of the bladder. Of the 310

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* In regard to this property, membranes differ in no respect from other animal textures, as was long ago proved by Chevreul. This distinguished philosopher found that the following substances absorbed, in 24 hours, of water, brine, and oil,—

	Cubic Centimetres Water.	C. C. Brine.	C. C. Oil.
100 grammes of cartilage of the ear . . .	231	125	—
100 " tendons	178	114	8.6
100 " yellow ligaments of spine .	148	30	7.2
100 " cornea	461	370	9.1
100 " cartilaginous ligaments . .	319	—	3.2
100 " dry fibrine absorbed . .	301 of water and 148 of alcohol of 69 per cent. (Liebig.)		
100 " "	184 parts by weight, or 154 by volume, of brine.		

volumes of water which become thus saturated with salt, only 133 volumes are retained in the bladder; and in consequence of this diminution of the absorbent power of the bladder for the brine, 177 volumes of liquid are expelled, and run off in drops from the surface of the bladder.

Membranes, fibrine, or a mass of flesh, behave exactly in a similar manner, when in contact with alcohol. If placed in alcohol in the fresh state, that is, when they are thoroughly charged with water, there are formed, at all points where water and alcohol meet, mixtures of the two, and as the animal texture absorbs much less of an alcoholic mixture than of pure water, more water is of course expelled than alcohol taken up.

Amount of water expelled from bladder by alcohol.

9.17 grammes of bladder, fresh, that is, saturated with water (in which are contained 6.95 grammes of water, and 2.22 of dry substance), when placed in 40 cubic centimetres of alcohol, weigh, at the end of 24 hours, 4.73 grammes, and have, consequently, lost 4.44 grammes. In the 4.73 grammes which remain are 2.22 grammes of dry bladder, and, of course, 2.51 grammes of liquid. If we assume that this liquid has the same composition as the surrounding mixture (which is found to contain 84 parts of alcohol to 16 of water), it will consist of 2.11 grammes of alcohol and 0.40 of water; and, consequently, of the 6.95 grammes of water originally present, 6.45 grammes have been expelled, and replaced by 2.11 grammes of alcohol. For 1 volume of alcohol, therefore, retained by the bladder, rather more than 3 volumes of water have been expelled from it.

Moist membranes shrink.

Since, in this case, so much more water is expelled than is taken up of alcohol, the first result is a shrinking of the animal substance.*

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* Fibrine and other animal matters exhibit results quite simi-

Dried salt placed in alcohol.

If the bladder could take up or absorb equal volumes of brine and water, or of alcohol and water, then, when the fresh bladder was strewed with salt, or laid in alcohol, the volume of the absorbed liquid would be unaltered, and an equal volume of saline solution, or of diluted alcohol, would be retained by the animal tissue. But since the absorbent power of the tissue for water is diminished by the addition of salt or of alcohol, it follows plainly, that a certain quantity of water must be expelled as soon as its character is changed by the addition of one of these substances.

The cause of this is the less affinity of the tissue for alcohol than for water.

The relation of bladder, fibrine, and other animal substances, when saturated with water, to alcohol and brine, proves that the shrinking (diminution of volume) of these tissues does not depend on a simple abstraction of water in virtue of the affinity of alcohol and of salt for that liquid; for it is quite certain that the attraction of alcohol to water, and that of water to alcohol, are respectively equal. The attraction of the water within the tissue for the alcohol without is just as strong as the power of the alcohol without to combine with the water within. Less alcohol is taken up, and more water given out, because the animal tissue has less attraction for the mixture of alcohol and water than for pure water alone. The alcohol without becomes diluted, the water within becomes mixed with a certain proportion of alcohol, and this exchange is only arrested when the

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lar to those obtained with bladder. 26.02 grammes of fibrine saturated with water (containing 6.48 grammes of dry fibrine and 19.54 of water) were reduced, in 45 grammes of absolute alcohol, to 16.12 grammes, losing, therefore, 9.90 grammes. Admitting the absorbed liquid to have the composition of the unabsorbed residue (70 per cent. of alcohol), it appears, that for 1 volume of alcohol absorbed by fibrine, rather more than 2½ volumes of water are separated.

attraction of the water for the animal tissue, and its attraction for alcohol, come to counterpoise each other.

If we regard a piece of skin or bladder or fibrine as formed of a system of capillary tubes, the pores or minute tubes are, in the fresh state, filled with a watery liquid, which is prevented from flowing out by capillary attraction.

But the liquid contained in these capillary tubes flows out of them as soon as its composition is altered by the addition of salt, alcohol, or other bodies.

Experiments.

If we lay together, one over the other, two portions of bladder, saturated with solution of salt of sp. g. 1.204, and over the upper one another piece of bladder of equal size, saturated with water, and if we allow them to remain thus, without pressure, we find, after some minutes, when the two pieces saturated with solution of salt are separated, that drops of saline solution appear between them, of which no trace could previously be perceived. If the piece of bladder saturated with water contained 5 volumes of water, and the next piece 3 volumes of saline solution, there must be produced, by the mixture of both, 8 volumes of diluted saline solution, of which each piece of bladder must contain one half, or 4 volumes, if the absorbent power of the portion saturated with the original saline solution were increased by the addition of water in the same ratio as the absorbent power of the portion saturated with water was diminished by the addition of salt. The saline liquid would have given up 1½ volumes of saline solution to the other, and would have received from it 2½ volumes of water. In this case, the mixture in the two upper pieces of bladder would occupy the same space which its constituents, water and saline solution, occupied in each singly. But the efflux of the liquid towards the third or lowest piece of bladder, saturated with saline solution, proves that the two upper pieces retain a smaller volume of the mixture newly formed in their pores than the one piece absorbed of water alone, and the other of saline solution alone. The power of retaining water is diminished by the addition of salt to the bladder saturated with water; liquid is expelled; but by the addition of this water to the bladder moistened with saline solution, the absorbent power of this piece of bladder is increased, not in the same ratio according to which the proportion of salt is diminished, but in a less ratio.

The experiments above described show that the attraction of the porous substances for the water which they have absorbed does not prevent the mixture of this water with other liquids.

Animal tissues are permeable to liquids of every kind,

The permeability of animal tissues to liquids of every kind, and the miscibility of the absorbed liquids with others which are brought in contact with the tissues, may be demonstrated by the simplest experiments.

If we moisten one side of a thin membrane with ferrocyanide of potassium, and the opposite side with chloride of iron in solution, we perceive in the substance of the membrane a spot of Prussian blue immediately deposited. (Joh. Müller.)

which act on each other in the substance of the tissues.

All fluids which, when brought together, suffer a change in their nature or in their properties, exhibit, when only separated by an animal membrane, exactly analogous results; they mix in the pores of the membrane, and the decomposition commences in its substance.

If we tie up one end of a cylindrical glass tube with bladder, and fill it to the height of 3 or 4 inches with water or strong brine, neither the water nor the brine flows out through the pores of the bladder under this slight pressure.

Deposit of salt on the outside of bladder from brine on the inside.

But if we leave the tube containing brine exposed to evaporation in the air, the side of the bladder exposed to the air is soon covered with crystals of salt, which gradually increase, so as to form a thick crust. It is obvious that the pores of the bladder become filled with brine; that, on the side exposed to the air, the water evaporates; its place is supplied by fresh brine, and the dissolved salt is deposited, at the external minute openings of the pores, in the form of crystals. If the tube be filled originally with dilute saline solution, the crust of salt is not formed on the outer surface of the bladder until the solution in the tube has reached, by evaporation, the maximum of saturation. Before this takes place, we can perceive in the tube, if we set the liquid in motion, two strata, a heavier and a lighter, the latter swimming on the former. When these strata can no longer be observed, the liquid is in every part saturated with salt, and now, by further evaporation, crystals are deposited on the outer surface of the bladder. This last circumstance proves that the amount of salt in the liquid is uniformly distributed from below upwards, from the specifically heavier to the specifically lighter part.

The solutions pass rapidly through water.

If we immerse the tube closed with bladder, and filled with saline solution, in pure water, the latter acquires the property of precipitating nitrate of silver, even when the contact has lasted only the fraction of a second. The brine filling the open pores of the membrane mixes with the pure water, and the latter acquires a certain quantity of salt.

In like manner, the pure water acquires a saline impregnation, when it is placed in the tube instead of brine, and the outer surface of the bladder is placed in contact with solution of salt.

When the tube, closed with bladder, and filled with brine, is left for a long time with the closed end immersed in pure water, the amount of salt in the latter increases, while that of the brine diminishes, till at last the two liquids, separated by the bladder, contain the same relative proportions of salt and water.

The same is true of milk and serum.

If the liquid in the tube contain, dissolved, other substances, which give to it properties different from those of pure water, and if these solutions be miscible with water, the mixture of them with the water takes place exactly as in the case of brine. This is true of saline solutions of every kind; of bile, milk, urine, serum of blood, syrup, solution of gum, &c., on the one side, and pure water, on the other. The concentrated liquid loses, the water or diluted liquid gains, in regard to saline impregnation.

If we fill the tube with water; and place it in a vessel with alcohol, the water becomes charged with alcohol, while the alcohol becomes diluted with water.

Change of volume when dissimilar liquids pass through bladder.

There is observed, in these circumstances, that is, when two dissimilar liquids, separated by a membrane, mix together, a phenomenon of a peculiar kind; namely, in most cases, a change of volume in both liquids, while the mixture goes on. The one liquid increases in bulk, and rises; the other diminishes in the same degree, and consequently sinks below its original level.

Endosmosis and Exosmosis.

This phenomenon of mixture through a membrane, accompanied with change of volume, has been distinguished by Dutrochet, under the name of *Endosmosis* and *Exosmosis; endosmose* is the name given when the volume increases, — *exosmose*, when it diminishes. Very generally, however, we attach to these terms the idea of the unknown cause or group of causes which, in the given case, produce the change of volume; in the same sense as that in which the term *capillary action* includes the causes which determine the ascent of liquids in narrow tubes.

In all cases, the increase in volume of the one liquid is exactly equal to the decrease in volume of the other, after making allowance for the contraction which the liquids undergo by simple mixture (as in the case of alcohol and water, oil of vitriol and water, &c.), as well as by evaporation. The unequal concentration or the unequal density of the two liquids has a decided influence on the rapidity with which the change of volume takes place; but this cannot be viewed as the cause of that phenomenon. In most cases, the denser liquid increases in volume; in others, the reverse occurs.

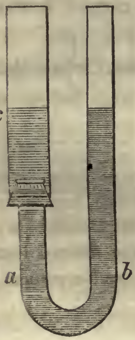
Change of volume does not depend alone on the different densities of the liquids.

When, for example, the tube contains brine, and the outer vessel pure water, the brine, that is, the denser liquid, increases in volume; but when the tube contains water, and the outer vessel alcohol, the water, that is, the denser liquid, diminishes in volume.

With regard to the mixture of the liquids, the bladder takes a distinct share in the process, inasmuch as it has pores, through which the two liquids are brought in contact.

With reference to the porosity of the bladder, the rapidity of the mixture of the two liquids is directly proportional to the number of particles which, in a given time, come into contact; it depends also on the surface (the size of the membrane), and on the specific gravity of the liquids.

Fig. 2.



Influence of the unequal density of the liquids

The influence of the extent of surface on the time required for mixture requires no particular elucidation; that of the unequal specific gravity is rendered evident by the following experiments.

when the lighter liquid is above the membrane.

If the bent tube *a b* (Fig. 2), one end of which is tied over with bladder, and the other open, be filled with brine colored blue,* and if pure water be placed in the tube *c*, there is soon perceived under the bladder a colorless or nearly colorless stratum of liquid, which continues for hours to float in the same place. If the bent tube *a b* be filled with colorless brine, while *c* is filled with pure water colored blue, there is found, after a time, *above* the bladder, a colorless or nearly colorless stratum of liquid.

It appears from this, that an exchange of both liquids goes on through the substance of the bladder; in the first experiment colorless water passes from the tube *c* to the colored brine in the tube *a b;* in the second, colorless brine passes from the tube *a b* to the colored water in the tube *c.*

It is obvious, that the brine in the tube *a b*, which is in contact with the bladder, becomes diluted by the addition of water from the tube *c;* but this diluted brine is specifically lighter than the original brine which is below it, and remains therefore floating at its surface.

On the other hand, the water in the tube *c*, when mixed with brine from the tube *a b*, becomes heavier than the pure water, and rests therefore on the upper surface of the bladder, or that which is turned towards the water.

Hence it follows, that from the moment when these two strata have been formed above and below the

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* For this purpose it is best to take a solution of indigo in sulphuric acid, diluted, and, after adding subacetate of lead as long as sulphoindigotate and sulphate of lead are precipitated, to separate the precipitate by filtration and dry up the filtered liquid in the water-bath. A mere trace of the blue residue suffices to give blueness to large masses of liquid.

bladder, neither concentrated brine nor pure water comes any longer in contact with the bladder.

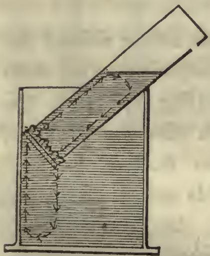
From the bladder downwards in the tube *a b* are strata of liquid, containing successively more salt; from the bladder upwards in the tube *c* are strata containing successively more water.

In the beginning of this experiment we observe that the volume of the water and of the brine changes in both tubes; the liquid in the limb *b* rises from 1 to 2 lines; but as soon as the strata above mentioned have been distinctly formed above and below the bladder, hardly any further rise is perceptible, although the mixture of the liquid proceeds, and the water in *c* becomes constantly more charged with salt, while the brine in *a b* loses salt.

When the heavier liquid is above the membrane.

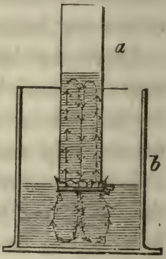
If we reverse the positions of the two liquids in the apparatus, Fig. 2, or, what is simpler, if we close with bladder a tube 1 centimetre ($\frac{4}{10}$ths of an inch) wide, fill it with brine, and immerse the end closed with the bladder in a wider vessel filled with pure water, giving to the tube an inclination of about 45°, we may observe (most distinctly when both liquids contain some fine particles of indigo suspended) in both liquids a continual motion. We see in the tube (Fig. 3) a current of liquid rising from the bladder in the direction of the arrow, and flowing down again on the opposite side. A similar circulation is observable in the vessel of water.

Fig. 3.



If the tube *a*, with brine, is about 2 centimetres ($\frac{4}{5}$ths of an inch) wide, and if we support it vertically in the vessel *b* of water, the motion proceds from the middle, and in both the tube and the vessel we perceive currents in opposite directions. (Fig. 4.)

Fig. 4.



These currents hardly require explanation. To the brine in the tube *a*, pure water passes through the bladder; there is formed above the bladder a mixture containing less salt, and therefore specifically lighter than the brine; this mixture rises, and the denser brine descends to occupy its place.

On the other hand, the pure water receives through the bladder salt, and becomes thereby specifically heavier; while it sinks to the bottom of the vessel, its place is supplied by water containing less or no salt, and therefore specifically lighter, which again comes in contact with the bladder. As long as the motions just described are perceptible, we observe a constant increase in the volume of the brine in the tube *a* (Fig. 4), or a diminution in the volume of the pure water in the vessel *b*. When the motions cease, the rise of liquid in the tube is arrested, and when this takes place, the two liquids are found to possess almost exactly the same specific gravity.

When the two strata of liquid on either side of the bladder are little different in composition (as soon comes to pass in the experiment (Fig. 2) where the saline contents of the liquid which fills the pores of the bladder can hardly vary from that of the next stratum), the mixture of the liquids takes place, but without further change of volume. But when an exchange of the mixtures on the opposite sides of the bladder can occur in consequence of their different specific gravity, and when a continued difference between the strata on opposite sides of the bladder is thus determined, then, so long as (in the case of brine and water, for example) one side of the bladder is in contact with a concentrated, the other with a more diluted solution, the change of volume in the two liquids continues.

As appears from these experiments, the change of volume depends on a difference in the character of the two liquids which are connected through the bladder; and the time during which change of volume occurs is in direct proportion to the time during which this difference in character subsists. The greater the difference in character and composition between the liquids, and the more rapidly this difference is renewed by the exchange between the strata in contact with the opposite sides of the bladder, the more rapidly does the one liquid increase, and the other diminish, in volume.

The change in volume made by a membrane

The following apparatus is very convenient for measuring the change in volume caused by the mixture of two liquids separated by a membrane.

Fig. 5.

The tubes *a* and *b* (Fig. 5) are of equal width, and are best taken from the same tube; *a* is closed with bladder, and filled up to a certain point with the liquid whose increase in volume is to be determined. It is then fitted by means of a good cork into the wider tube *c*, which contains distilled water, care being taken to exclude all air-bubbles. At *d* lies a small lead drop, which acts as a valve in shutting the opening of the capillary tube connecting *c* with *b*. Pure water is now poured into *b*, and in order to keep in equilibrium the lead drop at *d*, rather more water is added than exactly suffices to bring the liquids to the same level in both tubes.

The liquid in *a* increases in volume, and the height to which it rises may be read off by means of any division into equal parts by measure; the level of the liquid in *b* sinks in an equal ratio. If we keep the liquid in *b*, by the addition of fresh water, at the original level, and if we ascertain the weight of the added water, by pouring it out of a dropping bottle, and determining the loss of weight in the dropping bottle, we learn at the same time the weight and the volume of the water which has risen from *c* into *a*. This apparatus admits, of course, of a number of variations and improvements. I have employed it to determine the relation between brine and water, under the circumstances just described. It appeared, among other things, that when the tube *a* is filled with saturated solution of sea salt, the volume of the liquid increased by nearly one half; that is, 200 volumes of such a solution increased to 300. These determinations are, however, not the object of the present investigation, and therefore I pass them over entirely.

The following arrangement (Fig. 6) will probably be found preferable to the one just described, in many cases. Its construction depends on the observation, that, for the phenomenon itself, and for the result of the experiment, it is entirely a matter of indifference whether the tube be closed with a single, double, or treble layer of bladder.* For experiments on very thin membranes which are permeable to liquids under a very low pressure, the apparatus (Fig. 5) is obviously better

Fig. 6.

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* In these experiments membranes of all kinds may be used. With the thinner membranes, such as the bladder of the calf

adapted. For the explanation of the phenomenon, we have to distinguish, —

1. The mixture of different liquids.
2. The change in their volume.

Cause of the motion of dissimilar liquids.

As to the mixture of two liquids of dissimilar nature and characters, this always depends on a chemical attraction. In a mixture of alcohol and water, or of brine and water, there is in every part the same proportion of particles of alcohol and water, or of salt and water. If, in the former, the lighter particles of alcohol lying at the bottom of the vessel were not retained in the place and arrangement which they occupy by the surrounding particles of water, they would undoubtedly rise towards the surface. In like manner, the particles of salt in the brine are sustained and prevented from sinking by the lighter particles of water which surround them.

Without an attraction, which all the particles of alcohol or of salt must have towards all the particles of water, or all the particles of water must have for all those of salt and alcohol, a uniform mixture cannot even be conceived. If but one particle of alcohol were less powerfully attracted than the surrounding particles, it would rise to the surface; and, in like manner, the particles of salt would, in consequence of their greater specific gravity, gradually occupy the bottom of the vessel, were it not that a cause prevents them from rising or falling; and this cause can be nothing but an attractive force, which retains them in the place where they happen to be.

Chemical attraction is the cause of the motion of liquids.

The cause which effects a change in the place or in the properties of the ultimate particles or atoms

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and the pig, the experiments are more rapidly completed than with the thicker, such as the gall-bladder and urinary bladder of the ox. The peritoneum of the ox and calf is preferable to all others. The tube *c* is tied with bladder under water.

of dissimilar substances, when these particles are in absolute contact, or at infinitely small distances from each other, as well as the cause which manifests itself as a resistance to such changes of place or properties, we call *chemical attraction;* and in this sense the mixture of two dissimilar liquids, the simple moistening of a solid body, the penetration and swelling of it by a liquid, are effects in which chemical affinity or attraction has a decided share; and although we are accustomed to limit the notion of affinity to such cases as exhibit a change perceptible to our senses, in the properties of the substances employed, as, for example, when sulphuric acid and lime, or sulphur and mercury, combine together, this limitation arises from the imperfect apprehension of the essence of a natural force.

Affinity is everywhere active between bodies in contact.

Everywhere, when two dissimilar bodies come in contact, chemical affinity is manifested. It is a universal property of matter, and by no means belongs to a peculiar class of atoms, or to a peculiar arrangement of these. But chemical combination is not, in all cases, the result of contact.

Combination is only one of the effects of affinity, and occurs when the attraction is stronger than all the obstacles which are opposed to its manifestation. When the forces or causes which oppose chemical combination — heat, cohesive attraction, electric attraction, or whatever they may be called — preponderate, then chemical combination does not take place; and effects of another kind are manifested.

Melted silver in a crucible, surrounded with red-hot coals, in a place, therefore, where we should hardly anticipate the presence of free oxygen, absorbs as much as ten or twelve times its volume of that gas. Metallic platinum exhibits the same property in a far higher degree; for from the atmospheric air, a gaseous mixture in which oxygen forms only the fifth part, that metal (in the form of a black powder) condenses on its surface, at the ordinary temperature, an enormous quantity of oxygen gas (without any nitrogen), and acquires thereby properties which it does not otherwise possess.* And when oxide of chromium, fragments of porcelain, or asbestos, at high temperatures, effect the combination of two gases, oxygen and hydrogen, or oxygen and sulphurous acid, which gases do not combine at the same temperature, unless when in contact with these solid bodies, it is to the chemical attraction or affinity of these solid bodies that we must ascribe this effect.

The solution of a salt in water is an effect of affinity, and yet no one property, either of the salt or of the solvent, is thereby altered, except only the cohesion of the saline particles.

Crystallization of sea salt.

Sea salt, the crystals of which are usually anhydrous, takes up, at very low temperatures, 38 per cent. of water of crystallization; not because any new cause acts which increases its affinity for the particles of water (for cold is no cause, but the absence of a cause), but because the higher temperature acted as an obstacle, opposing their chemical combination. The force of affinity is all the time present and undiminished.

Precipitation of salt from its solution by alcohol.

When we add alcohol to the solution of a salt in water, we observe that now the salt separates from the liquid in the form of crystals, doubtless only because, by the addition of another chemical force, the amount of attraction between the particles of the salt and those of the water has been altered.

The aqueous particles, which were combined with

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* According to Doebereiner, platinum black condenses 252 times its volume of oxygen. Its effect in oxidizing alcohol, pyroxilic spirit, &c., is familiar to every chemist. — W. G.

the saline particles, manifest an attraction for the particles of alcohol; and as the latter have no affinity, or only a very feeble affinity, for those of the salt, the attraction of the saline particles for each other is strengthened. This attraction was present in equal force before the addition of the alcohol, but the resistance which opposed their union (the chemical attraction for them of the aqueous particles) was more powerful. The alcohol was not the cause of the separation. The cause of the separation of the salt from the liquid, its crystallization, is at all times the force of cohesion; and by the alcohol the cause which opposed its manifestation was removed.

Precipitation of sulphate of potash by potash.

The affinity of potash for sulphuric acid is known, and sulphate of potash readily dissolves in water. If we add to a saturated solution of that salt an equal volume of aqua potassæ of sp. g. 1.4, there is immediately formed a crystalline precipitate of sulphate of potash, and the sulphuric acid is separated in this form from the water.

In these cases the chemical effect (the separation) depends on the presence of a certain quantity of the liquid which is added (such as aqua potassæ, alcohol, &c.); but in many other cases there is required only a slight alteration in the quality of the solvent to effect separations of this kind.

Precipitation of hydroferrocyanic acid by ether.

When hydrochloric acid is added to a solution of ferrocyanide of potassium, hydroferrocyanic acid is set free, and remains dissolved in the liquid. If now the vapor of boiling ether be passed through the mixture, there occurs, after a few moments, a complete separation. The whole of the hydroferrocyanic acid is deposited from the liquid in the form of white or bluish-white crystalline scales, which generally appear in such quantity as to render the whole mass semi-solid.

In proportion as the vapor of ether is dissolved by the water, the latter fluid loses entirely its solvent power (its affinity) for the hydroferrocyanic acid. The coagulation of albumen by ether depends on a similar cause.

The capacity of solids to become moistened by liquids, and, in short, all phenomena connected with chemical affinity, are affected, altered, increased, or destroyed by causes quite analogous.

After heavy rains, the water of many rivers becomes turbid and opaque from the presence of a fine clay. These suspended particles of clay are so fine as to pass through the finest filters; and their adhesion to the water is so great, that such water does not clear after standing for weeks. The water of the Yellow River, in China, possesses, during the greater part of the year, this character; and from the French missionaries we know that alum is universally employed in Pekin to clear it. In fact, if a crystal of alum be held in such a water only for a few seconds, we observe the sediment separating in large, thick, flocculent masses, the water becomes transparent, and hardly a trace of dissolved alum is to be detected by the most delicate reagents. Chemistry is acquainted with a number of similar means for causing the separation from liquids of suspended precipitates.

In these cases we see, that, by an alteration of the quality of the water, produced by what we call mere mixture with a foreign body, its power of combining with others is destroyed or weakened.

Action of solids on dissolved matters.

It is well known that the force with which, in a solution, the particles of the liquid and those of the dissolved body attract each other is very unequal in different cases; and in this point of view the action of many solid bodies on saline solutions is very remarkable, inasmuch as it is thereby demonstrated that the molecular force, which determines the phenomena of cohesion, and the moistening of solid bodies by liquids, appears to be identical with chemical affinity, since chemical compounds can be decomposed by means of it. Professor Graham has shown that common charcoal, deprived by acids of all soluble ingredients, completely removes the metallic salts or oxides from solutions of salts of lead, tartar emetic, ammoniated oxide of copper, chloride of silver in ammonia, and oxide of zinc in ammonia; while other solutions, such as that of sea salt, suffer no such change. A bleaching solution of hypochlorite of soda loses entirely its bleaching properties by agitation with charcoal; and iodine can be removed by the same means from its solution in iodide of potassium. Every one is familiar with the action of finely divided platinum, with that of silver, on the deutoxide of hydrogen; as well as with that of charcoal on dissolved organic matters, coloring matters, &c.; and freshly precipitated sulphuret of lead, sulphuret of copper, and hydrate of alumina resemble the latter in their action. Many organic substances, such as woody fibre and others, act on dissolved matters, such as salts of alumina or of oxide of tin, just as charcoal does; and we know that the application of mordants in dyeing, and dyeing itself, depend on this very property. The adhesion of the solid coloring matter to the cloth which is died with it is the result of a chemical affinity so feeble, that we hardly venture to give the molecular force that name in this case. From a piece of woollen cloth dyed with indigo, the indigo is completely separated, by mere beating, continued for some time, with a wooden hammer, so that the wool is at last left white.

The surface of the solid body exerts, as these facts prove, a very unequal attraction on the molecules which come in contact with it.

Researches on capillary attraction have shown, that, with one and the same liquid, water, for example, the substance of the solid body has no influence on the height to which the liquid rises on it. On slices of box-wood, clay-slate, or glass, the rise of the liquid above the surface of the water is the same exactly as in the case of a plate of brass. (Hagen.) In the case of other liquids, the particles of which are entirely homogeneous, the same law may be assumed in theory; but with such liquids as contain foreign bodies in solution, a change in the capillary attraction must be produced by the presence of these bodies, because by them the cohesion of the liquid is altered; and perhaps still more, because the liquid ceases to be homogeneous when the attracting wall has a stronger affinity for the particles of the dissolved body than for those of the solvent.

From what has been stated, it appears that the mixture of two liquids is the result of a chemical attraction; for how otherwise could chemical compounds, such as the solution of a salt in water, be decomposed, or a chemical attraction be overcome, by its means?

Laws of the mixture of two dissimilar liquids.

Two liquids of different chemical properties, which are miscible together, and which, therefore, have a chemical attraction for each other, mix readily at all points where they come in contact. By motion, shaking, &c., the number of points of contact within a given time is increased, and the formation of a uniform mixture is thus accelerated.

If these liquids be of equal, or still better, of unequal, specific gravity, they may be, with the aid of some precaution, stratified one above the other. This is, in point of time, the most unfavorable case for the mixture, since proportionally small surfaces come in contact. But wherever they do come in contact, it is, after a very short time, impossible to detect any limit between them.

In a cylindrical vessel, containing solution of salt, the saline particles at the surface are attracted and sustained by aqueous particles, which exist at the sides of the saline particles, and from the surface downwards. From the surface upwards, the attracting aqueous particles are absent.

Now it is evident, that, when the surface is brought in contact with pure water, a new attraction is added to those previously existing, which acts in an opposite direction, namely, the attraction of the aqueous particles floating on the surface for the saline particles, and *vice versâ* (the attraction of the saline particles to the aqueous particles in contact with them).

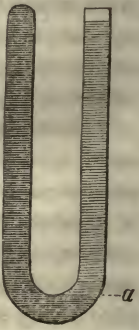
At the place where pure water and brine are in contact, there is thus formed a uniform mixture of the two, which upwards is in contact with pure water, downwards with brine.

Among these three strata, of which the upper contains no salt, the lower less water, a new division takes place; the more strongly saline stratum loses salt, the pure water becomes saline, and in this way salt and water are at last uniformly distributed throughout the liquid.

Experiments showing the formation of a mixture of two liquids.

If we fill the limb of the tube (Fig. 7), as far as *a*, with brine colored blue, and the other limb with water, we find, in the course of a few days, the water colored blue, and the proportion of salt in both limbs equal. It has been mentioned at p. 141, that in a tube closed with bladder, filled with diluted solution of salt, and exposed to evaporation, the salt is not deposited in crystals on the outer surface of the bladder till the whole liquid in the tube has reached, in consequence of evap-

Fig. 7.



oration, the maximum of saturation. The water evaporates from the exterior of the bladder, but no salt is deposited as long as a liquid exists within which salt can still dissolve; and in this way the heavier saline particles are distributed towards the interior, and upwards through the whole liquid, or, what amounts to the same, the lighter aqueous particles, which can still dissolve salt, are distributed downwards towards the external surface of the bladder.

The distribution of salt through water resembles the conversion of iron to steel by cementation.

This distribution of salt through water takes place in the same manner as the conversion of bar iron into steel. Rods of malleable iron, as is well known, are kept ignited between strata of charcoal, whereby the surface of the iron in contact with the charcoal takes up carbon, and becomes a carburet of iron. The stratum of iron lying next under this surface, which has the same attraction for carbon, acquires carbon from the superficial stratum immediately in contact with it, and in its turn gives carbon to the stratum below itself. This process, if continued long enough, has no limit till all the strata of particles have acquired an equal proportion of carbon, that is, till they are all saturated with it. A piece of red-hot malleable iron, if kept a few moments in contact with pig iron (a carburet of iron), is found to be already converted into steel at the points of contact. The mixture of liquids depends on the same principle; and we may suppose that their distribution is mutual, because their particles may move in all directions, and that consequently saline particles move towards aqueous particles, as well as aqueous towards saline particles, in virtue of their mutual attraction.

From a solution of sulphate of copper in ammonia, placed in a tall glass cylinder, there is gradually separated, if we pour a stratum of alcohol on the surface, and if we prevent the formation of a coherent crust which impedes the contact of the liquids, the whole of the ammoniated sulphate of copper, while the deep blue solution becomes colorless, because by the distribution of the alcohol through the solution a mixture is formed, in which the salt is insoluble.

Mixture is produced by chemical affinity,

The rapidity of mixture of two liquids depends on the degree of their chemical affinity; and the unequal mobility of the particles of one or the other liquid has a favorable or unfavorable influence on the result.

by unequal mobility, and by unequal density of the liquids.

When the one liquid is heavier than the other, and of tough, viscid consistence, a much longer time elapses before the ingredients of the tougher or heavier liquid reach the surface from the bottom of the vessel; and in this case the greater density and the less mobility of the particles are obstacles to the mixture.

On the other hand, if the heavier or more viscid liquid be placed above the lighter, the mixture takes place rapidly; at the points where both liquids are in contact is produced a mixture, which, being heavier, descends, whereby the heavier liquid above is continually brought in contact with new surfaces of liquid.

Effect of position on the solution of a solid.

The very same phenomenon is observed in solution. A fragment of sugar, when covered with water at the bottom of a narrow cylinder, dissolves very slowly, while, if suspended just below the surface, it rapidly disappears. In the former case there is produced round the sugar a thick, syrupy, viscid solution, which protects the undissolved part of the sugar for a long time from contact with the water; in the latter, there is formed at the surface a solution, which descends in striæ, and gradually disappears, while, by the change of place thus induced, new portions of water are constantly brought in contact with the undissolved sugar, and are thus enabled to exert their solvent powers.

If skin and membranes consist of a cohering system of very narrow tubes, it is obvious that when two dissimilar but miscible liquids are separated by such a tissue, the pores of the tissue will fill with each of the two liquids. In all situations where the liquids come in contact in the substance of the membrane, a mixture takes place, and this mixture is extended equally towards both sides.

If there be brine on one side of the bladder, and water on the other, there must be formed, in the middle, or at some point of the bladder, a diluted brine, which on the side in contact with the water yields salt to that water, while on the opposite side the strong brine mixes with the diluted brine in the bladder.

The substance of the bladder has no influence on this mixture, because it can produce no change of place on the part of the saline or aqueous particles, for this is the result of the chemical affinity acting between the particles of salt and those of water.

Rapidity of mixture.

Now, since the rapidity of the mixture of two liquids stands in a direct proportion to the amount of their surfaces coming into contact within a given time, and since the liquids, separated by a bladder, can only come in contact through its pores, while the number of points of contact is diminished by the presence of the non-porous parts of the bladder, it follows, that, exclusive of all other effects, the time required for mixture must be lengthened by the interposition of a bladder. In the absence of the bladder, the mixture would take place exactly as when it is present, except in regard to time.

When the heavier brine is under the water above the bladder, the two liquids mix more slowly than without the bladder.

In certain circumstances

But since a bladder, inasmuch as a feeble hydrostatthe interposition of a membrane accelerates mixture.

ical pressure is not propagated through its pores, allows us to place a heavier liquid above a lighter, and to retain it in that position, this circumstance has the effect of promoting mixture, the ultimate cause of which is, not the bladder, but the specific gravity of the liquid. The bladder is a means of enabling the specific gravity to influence mixture. The foregoing remarks appear to me sufficiently to elucidate the share taken by the bladder in the mixture of two dissimilar liquids placed on opposite sides of it.

Change of volume in two liquids which mix through a membrane

With respect to the change of volume in the two liquids which become mixed through the bladders, we must consider that the moistening or the absorbent power of a solid body, as well as the power of a liquid to moisten other bodies, is the result of a chemical action.

is the result of chemical affinity modifying capillary attraction.

Liquids of different properties, or of different chemical characters, are attracted with unequal degrees of force by solid bodies, and exert towards them unequal degrees of attraction, and if we alter even in a system of capillary tubes, filled to a certain height with a liquid, the chemical nature of that liquid, we change thereby the height at which the liquid stands. In an animal tissue saturated with water, the water is prevented from flowing out by the mutual attraction, and by the capillary force, but if the attraction of the organic parietes for water be diminished by the addition of alcohol or of salt to the water, a part of it flows out. To this must be added, that the water absorbed by an animal texture when it enters the capillary tubes exerts, in virtue of its attraction for the tubes, a certain pressure, by which the vessels are swollen and enlarged. The particles of liquid in these tubes undergo a counterpressure from the elastic parietes, by which pressure, when the attraction of the liquid particles for the solids is diminished by any new cause, the amount of expelled fluid is increased.

The organic parietes of the tubes, saturated with water, are affected by alcohol just as a salt is when dissolved in water. On the addition of alcohol, or of another liquid, the water separates from the salt, or from the parietes, or the parietes separate from the water.

If the animal tissue possessed as great an attraction for the newly formed mixture as for the water alone, the volume of the liquid would not change. The mixture would take place, but no water would flow out.

A bladder, saturated with water, when brought in contact with alcohol, shrinks together, a part of the water separates from the animal matter, but there always remains in the bladder a certain amount of water, corresponding to its attraction for the bladder and for the alcohol; just as the solutions of many salts which have a strong attraction for water (such as metaphosphate and acid phosphate of soda), and are insoluble in alcohol, are separated by the addition of alcohol into two strata of liquid, the heavier of which is a more concentrated solution of the salt in water, containing a little alcohol, while the other, the lighter, is an aqueous liquid containing much alcohol. The alcohol and the salt divide between them the water of the solution.

Action of chloride of calcium on a mixture of acetone and water.

When we add, to a mixture of equal parts of acetone and water, a certain quantity of dry fragments of chloride of calcium, the first fragments which are added deliquesce and dissolve entirely in the mixture. But if we go on adding the salt, a separation soon occurs, two strata of liquid are formed, of which the upper contains acetone and water, the other is an aqueous solution of the chloride with a little acetone. If we add still more of the chloride, water is abstracted from the acetone of the upper stratum, and when a proper quantity has been added, the acetone retains no trace of water.

If we suppose, that of the two originally formed strata of liquid, one of them, namely, that which sinks and contains chloride of calcium dissolved, is in contact with a current of dry air, the water of this solution will evaporate, the solution will thus become stronger, and in consequence of its increased concentration will be able to remove a new portion of water from the mixture of acetone and water above it; and this will continue till the acetone is entirely deprived of water.

If in the place of the chloride of calcium we put a bladder, and, in place of the acetone and water, diluted alcohol, we have the finest example of the unequal attraction which the animal tissue exerts on the two ingredients of the mixed liquid.

Effect of evaporation upon a mixture of alcohol and water in a bladder.

It is known, from the experiments of Soemmering, that spirits of a certain strength inclosed in a bladder, which is exposed to the air, lose by evaporation only water, and that at last anhydrous, or nearly anhydrous (absolute), alcohol is left in the bladder. When strong spirits of wine are used, the bladder remains dry externally; when weaker spirits are employed, it becomes moist, and alcohol evaporates with the water. In virtue of the unequal affinity of the bladder for alcohol and for water, a complete separation is here effected. The water of the mixture is absorbed, and evaporates from the outside of the bladder; the alcohol remains in the bladder. As yet, we are acquainted with no substance which can replace the bladder in this operation; and indeed the affinity of the gelatinous tissues (membranes, &c.) for water must exceed that of all other animal tissues, since a rise of temperature, of a few degrees only, suffices to enable water to dissolve that tissue perfectly into a jelly.

Views of Magnus on Endosmosis.

Magnus assumes "that the particles of every solution, for example, of a salt in water, adhere more strongly to each other than do those of the solvent, for example, of water; consequently, the solution would be less fluid, and pass with greater difficulty through very narrow openings, than water, if we take for granted that the parietes of the openings act alike towards both. It would follow from this, that, the more concentrated a solution, the less easily would it pass through the same openings."

"Let us now try," pursues Magnus, "with the aid of these assumptions (which, as appears from the experiment, Fig. 1, are perfectly accurate and demonstrable for many saline solutions, although there are, according to the researches of Poiseuille, a number of exceptions*), to explain the phenomena of Endosmosis."

"Both the brine and the water will penetrate into the pores of the bladder, and brine will pass from the pores to the water, as well as water to the brine, in virtue of their mutual attraction, till a complete equilibrium is established. Further, since the force which attracts the water to the brine is exactly the same as that which attracts the brine to the water, as much water as brine would pass through the bladder, if both liquids could pass with equal facility through the pores. Since, however, this is not the case, unequal forces are required to urge the two liquids through the pores; or, with equal forces, unequal quantities of the two pass through in equal times. There is, consequently, added more of that which passes most easily, the water to the brine, than of the latter to the water, and the level of both liquids must change, if no other force oppose this change." †

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* Ann. de Ch. et de Phys., 3d Series, XXI. pp. 84 *et seq.*

† Poggendorff's Annales, X. p. 164.

According to this theory, brine and water exist in the pores of the bladder in a state of motion, and the chemical affinity which the particles of the brine have for the particles of the pure water, and, conversely, which the particles of water have for those of salt, is considered as the cause of this motion. The unequal velocity, which makes more water flow in a given time to the brine than brine or salt to the pure water is, according to Magnus, determined by the unequal resistance which the substance of the bladder opposes to the passage of the two liquids.

Now, however narrow the tubes may be in which molecules are set in motion by an external force, it may always be assumed, that that part of the molecules which is immediately in contact with the wall of the tube either is not in motion, or possesses only a small velocity, and the velocity of efflux must be a function of the cohesion, and at all events not dependent on the wall of the tube.

If now the efflux of the water on one side of the bladder is produced by the attraction of the saline particles for the water, and the efflux of the brine on the other side is produced by the attraction of the aqueous particles for the saline particles, it is impossible to explain how water and brine can move in the same tube with unequal velocity in opposite directions; the two liquids being supposed to have a mutual attraction, that is, to be miscible. This attraction must act within the tube just as well as without; and we might therefore suppose, that, when the two liquids have become mixed, the mixture could only move in one direction with a medium velocity.

Assuming that a mixture is formed in the open orifices of the pores or tubes, or in any part of them, it is difficult to see why saline particles should not pass from one side to the water, or aqueous particles to the saline ones in the bladder, since the mutual attraction must be regarded as equal on both sides. The chemical affinity of the two liquids does not explain the efflux.

If we suppose, that in certain pores only brine, in others only pure water, moves, the phenomenon ought not to occur when all the pores are filled with water or with brine, or when the tube is tied with a double, treble, or fourfold bladder. But the properties of bladder are seen in the finest as well as thickest membranes, and one, two, or three layers make no difference in the ultimate result.*

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* With respect to the theory, that, when a saline solution is mixed with pure water, if the two liquids are separated by a membrane, particles of salt alone pass through the pores of the bladder to the water, and particles of water alone to the brine, the following experiments may throw some light on the question. For the sake of greater accuracy, the results were determined by weighing. The apparatus Fig. 3 was used. The tube contained 8.67 grammes of saturated brine, in which were 2.284 grammes of salt and 6.38 of water. After 24 hours it had gained 1.79 grammes in weight, and it now contained only 0.941 grammes of salt. It had, therefore, lost 1.343 grammes of salt, and gained 3.13 of water. According to the above theory, 1 atom of salt and 15 atoms of water must have moved past each other; but this is impossible, since 1 atom of salt requires 18 atoms of water for solution (10 parts of salt to 27 of water). The weight of the pure water in the outer vessel was 19.26 grammes; consequently, the weight of the brine was to that of the pure water as 1 : 2.22. In another experiment, in which the weight of the brine in the tube was to that of the water outside, as 1 : 7.98, the tube gained 0.822 grammes in weight; the liquid in the tube contained at first 0.947 grammes of salt; and 24 hours after, 0.148 grammes: hence, 1.621 grammes of water had entered, while 0.799 grammes of salt had passed out. For 1 atom of salt, which passed from the tube with brine to the vessel with water, there passed from the latter to the former rather more than 13 atoms of water (for 58.6 parts, or 1 atom of salt, 118 parts of water).

The nature of the membrane has an important influence.

The kind of influence which the nature of the partition, or its attraction for the liquids in contact with it, exerts on the phenomenon, is seen by comparing the action of an animal membrane with that of a thin sheet of caoutchouc.

Experiments with bladder

In a tube, closed with bladder, which is filled with alcohol and immersed in pure water, the volume of the alcohol is increased; more water passes to the alcohol than alcohol to the water.

and caoutchouc.

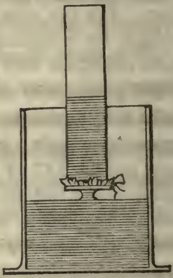
If, without making any other change in the experiment, the tube be closed with a thin sheet of caoutchouc, the volume of the alcohol now diminishes, while that of the water increases.

Here, all the circumstances of the mixture of the two liquids have remained the same, except the nature of the partition, which makes the difference in the result.

Experiment to prove the attraction of the bladder for the liquid.

When we fill with brine a tube closed with bladder (Fig. 8), and place it in a vessel of water, so that the bladder and water only communicate by a single drop, the liquid in the tube increases in bulk, and rises in the tube, as if the bladder had been immersed in the water; but the drop becomes gradually smaller, till, after an hour or two, a complete separation takes place, and the drop tears itself away from the water.*

Fig. 8.



If the cause of the change of volume in this exper-

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* If we pour into a tube ¼ of an inch wide, and closed with bladder, as much mercury as covers the surface of the bladder, then fill it with brine, and place it in pure water, the volume of the liquid in the tube increases exactly as if the mercury were not there.

Unequal attraction of membrane for different liquids.

iment were the unequal resistance which the bladder opposes to the passage of the two liquids with equal attraction (equal force) on both sides, the phenomenon just described would be inexplicable; for a resistance can no doubt impede, but is not capable of producing, motion. But we see that the water in this experiment is raised to a higher level, and, moreover, the tearing asunder of the drop can only be the effect of a powerful attraction, residing in the substance of the bladder.

If the moistening of solid bodies by liquids be the effect of a chemical attraction, the force of which is different in dissimilar liquids, it follows, that when a porous body is saturated with a liquid, and brought in contact with a second liquid, which has a stronger attraction for its substance than the first has, then the first liquid must be displaced from the pores by the second, even in the absence of hydrostatic pressure, and this whether the two liquids be miscible or not.

We may suppose that the attraction of the second liquid, of more powerful affinity, which displaces the other, is equal to the pressure of the column of mercury required to force the latter through the porous substance.

If we tie over one end of a cylindrical tube with a very thin membrane, saturated with concentrated brine by steeping for 24 hours, and if we dry the outer surface of the membrane carefully with bibulous paper, and now pour a few drops of pure water into the tube so as just to cover the inner surface of the membrane, the outer surface is seen in a few moments to be covered with minute drops of brine; that is, brine flows out of the pores of the bladder.

A thick ox-bladder, saturated with oil, exhibits the same phenomenon in contact with water. The oil is expelled from the pores of the bladder by the water, which occupies its place.

Explanation. When the bladder is brought in contact with pure water, it takes up a certain quantity of that liquid. If its pores are previously filled with brine, and if we cover one side of it with pure water, the water mixes with the brine in the pores of the bladder ; and on the side next the water there is formed a diluted brine, which, being in contact with a stratum of pure water, mixes with it, and in this way the successive strata of water receive, from the bladder outwards, a certain quantity of salt.

In the interior of the bladder, there are formed in like manner, towards the outer surface, mixtures of unequal saline strength. If we suppose the bladder to consist of several strata, all these strata receive, from the surface in contact with the water, a certain quantity of water; the outer stratum, in contact with the air, receives least, and is the most highly charged with salt.

The cause of mixture is the chemical affinity of the salt for the newly added particles of water; this affinity is equal on both sides, but the attraction of the substance of the bladder is stronger for the more aqueous or less saline liquid than for the more concentrated. In consequence of this difference in the attraction of the liquids for the substance of the bladder, a part of the mixture is displaced from the bladder; the less saline liquid takes the place of the more saline ; a part of the latter is expelled, and with it a part of that water which has been added to the outer stratum by mixture. Brine and water flow out in the direction of least resistance. The efflux towards the side on which the pure water was poured is prevented by the stronger attraction of the more watery liquid for the substance of the bladder.

If we remove from the outer surface of the bladder the displaced saline liquid (which has been mixed with some water), and put stronger brine in its place, and if on the opposite side we remove the very diluted solution, replacing it by a still more diluted one, the same process is repeated. There arises a permanent difference, and a state of mixture and efflux continues till the liquids on the opposite surfaces of the bladder have the same, or very nearly the same, composition.

If we suppose that the two liquids moisten the bladder unequally, it follows, that, in addition to the chemical attraction which the dissimilar particles of the liquids have for each other, a new cause, namely, the stronger attraction of one of them for the substance of the partition, is introduced, which accelerates their motion or passage, and must have this effect, that one of them flows out in larger quantity, in the same time, than the other.

Mixture essentially determined by the unequal density of the liquids.

The experiments (Fig. 3) elucidate this process, and show besides, that the exchange of the two liquids on both sides of the bladder is essentially determined by their unequal specific gravities. As long as the difference in their composition (which may here be measured by the specific gravity) is very great, the change of volume (increase of one and decrease of the other) takes place rapidly; but at last, when this difference becomes very small, the liquids mix without further visible change of volume, obviously, because the attraction of the bladder to the mixtures on the opposite sides does not perceptibly differ, although the specific gravities are still somewhat unequal.

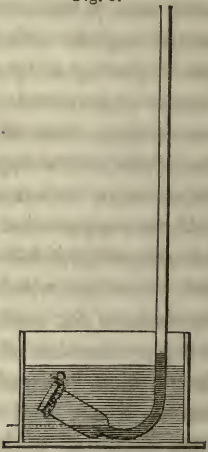
The action of two liquids upon animal tissues is equivalent to a mere change in

In the ultimate result, the action of dissimilar liquids on the substance of animal tissues, in consequence of which their mixture is attended with a change of volume, appears to be equivalent to a mechanical press-

pressure unequal on opposite sides.

ure, which is stronger from one side than from the other.

Fig. 9.



If the tube (Fig. 9), which is closed with bladder at its wide opening, be filled with brine to the mark *a*, if so much mercury be then poured into the narrow vertical part as by its pressure to cause brine to begin to flow out in fine drops from the pores of the bladder, and if now, after removing so much of the mercury that the efflux is no longer visible, we place the apparatus in a vessel with pure water, colored blue, as in the figure, the mercury does not change its level; and when, after one or two hours, we carefully remove the tube from the water, we find that in the upper part of the wide end of the tube, which contained colorless brine, a dark blue stratum has been formed, which floats on a colorless liquid. After a longer time, the blue color spreads gradually downwards, till at last the brine acquires a uniform blue tint.

It will readily be perceived, that the two liquids here mix, as if no pressure had been applied to the brine, for a mechanical pressure exerts no influence on the mixture; but, in consequence of the pressure, the mixture takes place without change of volume. The mechanical pressure which the water, in virtue of its stronger affinity for the bladder, exerts on the brine in the pores of the bladder, is held in equilibrium by the column of mercury, and the result is, that exactly as much brine flows out as water flows in.

Additional example.

Let us suppose the column of mercury to be removed, and the rise of the brine in the narrow tube is explained at once. If we close a short tube, filled with alcohol or brine, with bladder at both ends (an arrangement which may represent a cell), and suspend it in a vessel of pure water, both surfaces of the bladder become convex outwards; they swell, but without bursting. As soon as the pressure, gradually increasing by the influx of water into the interior of the tube, is sufficient to keep in equilibrium the affinity of the water for the bladder, and consequently its further influx, the exchange goes on, for the future, without change of volume.

Porous bodies generally exhibit similar phenomena.

Most porous bodies exhibit the phenomena described in the preceding pages, if their pores are so minute that a feeble hydrostatic pressure is not propagated through them. These phenomena may be produced with clay cells * (such as are used for galvanic appa-

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Among liquids absorbed by porous baker's clay.

* I consider it of sufficient importance to state here that porous clay also takes up unequal volumes of brine and water. In special experiments made on this subject, cells of clay (moderately ignited porcelain biscuit) were laid for 24 hours in pure water, then carefully dried externally with bibulous paper, and the increase in weight, that is, the weight of the absorbed water, carefully determined. The clay was then carefully dried, laid for 24 hours in brine, and the weight of the absorbed brine determined in like manner. In a second series of experiments, the clay cells were steeped in water and brine, and placed in the receiver of the air-pump, under a pressure of 8 lines of mercury ($\frac{2}{3}$ds of an inch) for 24 hours.

Under the ordinary pressure, and in air, the cells absorbed

		Weight.		Volume.	
		Water.	Brine.	Water.	Brine.
100 parts of clay cell	I. —	15 4	14.6	15.4	12.2
	II. —	11.8	11.6	11.8	9.7

In vacuo, the cells of clay absorbed

		Weight.		Volume.	
		Water.	Brine.	Water.	Brine.
100 parts of clay cell absorbed	I. —	16.5	16.8	16.5	14.0
	II. —	13.8	13.8	13.8	11.5

ratus); with the lining membrane of the pods of peas and beans; with the fine inner bark of trees; with the skin of grapes, of potatoes, of apples; with the inner membrane of the capsules of bladder senna, &c.; but animal tissues surpass all others in efficacy. Besides their unequal affinity, they have an unequal absorbent power for dissimilar liquids, by which their action in causing change of volume during mixture is strengthened.

Effect when the tube is immersed in brine or alcohol.

When a tube, closed with bladder, and filled with water, is immersed in alcohol or brine, there is produced at all points, where the brine or the alcohol comes in contact with bladder saturated with water, a change in the properties of the bladder. When, in the open pores, the alcohol or brine mixes with the water already there, the absorbent power of the bladder for the water is diminished; a smaller volume of the mixture is retained than of pure water; that is to say, water flows out in the direction of the alcohol or brine. This efflux is accompanied by a change in the volume of the substance of the bladder, for that side of it which is towards the alcohol or the brine contracts or shrinks.

The opposite surfaces of an animal membrane, in contact with dissimilar liquids, for which they have unequal absorbent power, are in an unequal state of contraction. This condition is permanent, as long as the liquids do not change in their properties; but it ceases in consequence of mixture, and is again restored when, by means of the change of place in both the liquids which are in contact with the opposite surfaces of the bladder, the original or any other permanent inequality or difference of properties is produced.

Change in the volume of two liquids

In all cases where a permanent change in the volume of two liquids, separated by a membrane, is observed during their mixture, it is always accompanied by a permanent difference in the nature or properties of the two liquids; and from this it follows, that the molecules of the animal membrane must be, during the mixture, in an alternate state of contraction and swelling, or dilatation; that is, *in a continual motion.*

separated by a membrane is accompanied by continual motion among the particles of the membrane,

From what has been stated, it appears that the change of volume of two miscible liquids, separated by a membrane, is determined by the unequal capacity of being moistened, or the unequal attraction of the membrane for these liquids. The unequal absorbent power of the membrane for these liquids depends on the dissimilar nature of the liquids or of the substances dissolved in them. An unequal proportion of the same dissolved matters (unequal concentration) acts in many cases just as if the liquids contained dissimilar substances.

and depends upon the unequal attraction of the membrane for the liquids.

Although the experiments hitherto instituted, and the results obtained by Fischer (who first observed these phenomena), Magnus, Dutrochet, and others, admit of no comparison, since the apparatus used by them showed only relative change of volume, yet a knowledge of some of these results is nevertheless of importance.

When the two liquids are diluted sulphuric acid (of sp. g. 1.093) and water, the acid, at 50° F., increases in volume; but if the acid have the specific gravity 1.054, the volume of the water increases.

Effect of dilution.

Diluted tartaric acid (11 parts of the crystallized acid and 89 of water) and water mix through a bladder without change of volume; with more than 11 per cent. of acid, the volume of the acid increases; with less, that of the water.

Solutions of animal gelatine, gum, sugar, and albumen increase in volume when separated by a bladder from water; and the increase of volume in these different solutions, although of the same specific gravity, is very different indeed. When the specific gravity is 1.07, the increase in volume of the solution of gelatine amounts to 3, that of solution of gum to 5, of sugar, 11, of albumen, 12. When a solution of sugar (1 part of sugar to 16 of water) is separated by a bladder from water, it increases in volume; but if we add 1 part of oxalic acid to the sugar, the water, on the contrary, increases in volume. If the amount of sugar in the solution be doubled, the liquids mix without change of volume. A solution of sugar, separated by bladder from one of oxalic acid, rises, in the same time, 3 times higher than when separated from water. (Dutrochet.)

Membranes have less power of absorbing solution of albumen than for all other substances.

From these experiments we obtain, as a universal result (which, however, requires confirmation), that an animal membrane possesses a less power of absorption for solution of albumen than for all other organic substances; and that a small amount of mineral or organic acids increases the power of transudation of water, as well as of the solutions of many organic substances.*

Effect of adding acids.

Causes which influence rapidity of mixture.

The rapidity of mixture of two liquids, separated by a membrane, depends on the thickness of the membrane, and stands in direct proportion to the velocity with which the mixture formed in the pores and on both surfaces of the bladder changes its place, and the orig-

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* In order not to be misled in such experiments, we must avoid the employment of all those liquids which alter the membrane in its chemical properties. Such are, for example, acids of a certain concentration, nitrate of silver, salts of lead, chloride of gold, chloride of tin, chromic acid, bichromate of potash, tannic acid, &c. Even in water, the properties of membranes generally undergo a change after some days; they then propagate a far weaker hydrostatic pressure through their pores, and are no longer fit for such experiments.

inal difference in the quality of the two liquids is renewed.

Action of intestine.

If we suppose a tube, formed of a membrane (an intestine, for example), and filled with water, and if we assume that a current of saline solution flows round this tube, in consequence of a mechanical force, the increase of volume of the brine (the passage into it of a certain amount of water) will be effected in a far shorter time than if the brine were not in motion.

Transference diminishes with the difference of properties between the liquids.

The velocity of transference will diminish with the amount of difference in properties between the two liquids (the different amount or percentage of salt); it will be greatest at first, and diminish as the dilution of the brine increases, in proportion, that is to say, as water is transferred from the contents of the tube to the liquid without.

The greatest effect occurs when the concentration of the brine is kept uniform.

The greatest effect, therefore, must occur and be permanent, when the water transferred to the brine is continually again removed from it, that is, when the concentration of the brine is kept uniform. To this end, if we suppose the membrane to be difficultly permeable for one liquid, while the other is easily taken up into its pores, and if we reflect that this second liquid, on entering into the pores of the bladder, in virtue of the attraction of their walls for it, acquires a certain velocity which permits it to pass beyond the extremities of the canal or of the pores, so as entirely to fill the pores, and to come in direct contact with the liquid on the outside of the pores, it follows, that, when this second liquid moves past the pores with a certain velocity, the absorbed liquid must follow it during the mixture, and there must take place a rapid transference of the second liquid to the first, — a true suction, as if by a pump.

The animal body an apparatus.

The animal body is an example of an apparatus of this kind in the most perfect form. The bloodvessels contain a liquid for which their walls are, in the normal state, far less permeable than for all the other fluids of the body. The blood moves in them with a certain velocity, and is kept at all times in a nearly uniform state of concentration by a special apparatus, namely, the urinary organs.

Absorption of the liquids into the intestines from the blood.

The whole intestinal canal is surrounded with this system of bloodvessels, and all the animal fluids, in so far as they are capable of being taken up by the parietes of the intestinal canal, and of the bloodvessels situated around it, are rapidly mixed with the blood. The volume of the blood increases, if no compensation is effected by means of the kidneys; and the intestine is emptied of the liquids contained in it. The intestinal glands, through which this transference is effected, and each of which represents a similar apparatus of suction, contain, within them, two systems of canals, — bloodvessels and lacteals; the bloodvessels are placed next to the external absorbent surface, the lacteals chiefly occupy the central part of the gland. The liquids circulating in these two systems have very unequal velocities, and as the blood moves much faster in the bloodvessels, we perceive how it happens that the fluids of the intestine are chiefly (in quantity and in velocity) taken up into the circulation.

Effects produced on the organism by water and saline solutions.

The difference in the absorbent power of the parietes of the intestinal canal for liquids which contain unequal amounts of dissolved matters is easily observed in the effects produced on the organism by water and saline solutions.

If we take, while fasting, every ten minutes, a glass of ordinary spring water, the saline contents of which are much less than those of the blood, there occurs, after the second glass (each glass containing 4 ounces), an evacuation of colored urine, the weight of which is very nearly equal to that of the first glass; and after taking, in this way, 20 such glasses of water, we have had 19 evacuations of urine, the last of which is colorless, and contains hardly more saline matter than the spring water.

Drinking sea-water.

If we make the same experiment with a water containing as much saline matter as the blood ($\frac{3}{4}$ to 1 per cent. of sea salt), there is no unusual discharge of urine, and it is difficult to drink more than three glasses of such water. A sense of repletion, pressure, and weight of the stomach point out, that water as strongly charged with saline matter as the blood requires a longer time for its absorption into the bloodvessels.

Solutions containing more salt than the blood.

Finally, if we drink a solution containing rather more salt than the blood, a more or less decided catharsis ensues.

The action of solution of salt is of three kinds, according to the proportion of salt. Spring water is taken up into the bloodvessels with great rapidity; while these vessels exhibit a very small power of absorption for water containing the same proportion of salt as the blood does; and a still more strongly saline solution passes out of the body, — not through the kidneys, but through the intestinal canal.

Enemata in water act as saline solutions.

Saline solutions and water, given in the form of enemata, exhibit similar phenomena in the rectum. Pure water is very rapidly absorbed, and excreted through the urinary passages. If we add to the water colored or odorous matters, these appear more or less changed in the urine. When a small quantity of ferrocyanide of potassium is added, its presence in the urine is very soon detected by chloride of iron, which forms with it Prussian blue. Of concentrated solutions, far less is absorbed in the same time than of diluted; in most cases, they mix with solid matters collected in the rectum, and are expelled in the form of a watery dejection.

Action of Glauber and Epsom salts compared with that of sea-water.

All salts do not act alike in this respect. In equal doses, the purgative action of Glauber salt and Epsom salt is far stronger than that of sea salt; and their power of being absorbed by animal membranes appears to be in the inverse ratio of this effect. It is hardly necessary particularly to point out that an explanation of the action of purgatives in general cannot be included in the above-described action of saline solutions on the organism. The example which has been given is intended to illustrate a physical property common to a large number of salts, and apparently independent of the nature of the acid or base of the salt; for chloride of calcium, chloride of magnesium, bitartrate of potash, tartrate of potash and soda, phosphate of soda, and certain doses of tartar emetic, show the same action as sea salt, Glauber salt, and Epsom salt, although the bases and acids in these different salts are not the same.

Solutions of cane sugar, grape sugar, sugar of milk, and gum, exhibit, when separated from water by an animal membrane, phenomena similar to those exhibited by the above-named solutions of mineral salts, without causing in the living body a purgative action, when of equal concentration. The cause of this difference may be, that the mineral salts, in their passage through the intestinal canal and through the blood, are not essentially altered in their composition, while these organic substances, in contact with the parietes of the stomach, and under the influence of the gastric juice, suffer a very rapid change, by which the action which they have out of the body is arrested.

Since the chemical nature and the mechanical character of membranes and skins exert the greatest influence on the distribution of the fluids in the animal body, the relations of each membrane presenting any peculiarity of structure, or of the different glands and systems of vessels, deserve to be investigated by careful experiment; and it might very likely be found, that, in the secretion of the milk, the bile, the urine, the sweat, &c., the membranes and cell-walls play a far more important part than we are inclined to ascribe to them; that, besides their physical properties, they possess certain chemical properties, by which they are enabled to produce decompositions and combinations, true analyses; and if this were ascertained, the influence of chemical agents, of remedies, and of poisons on those properties would be at once explained.

The phenomena not confined to the gelatinous tissues.

The phenomena described in the preceding pages are observed, not in the gelatinous tissues alone, but also, apparently, in many other structures of the animal body, which cannot be reckoned as belonging to that class.

Coagulated albumen acts like thin membrane.

If we tie moist paper over the open end of a cylindrical tube, and, after pouring in above the paper white of egg to the height of a few lines, place that end of the tube in boiling water, the albumen is coagulated, and when the paper is removed, we have a tube closed with an accurately fitting plug of coagulated albumen, which allows neither water nor brine to run through. If the tube be now filled to one half with brine, and immersed in pure water, as in Fig. 4, the brine is seen gradually to rise; and in three or four days it increases by from $\frac{1}{4}$ to $\frac{1}{2}$ of its volume, exactly as if the tube had been closed with a very thick membrane.

Influence of the Cutaneous Evaporation on the Motion of the Fluids of the Animal Body.

Influence of cutaneous evaporation on the motion of the animal juices.

When a tube, about 30 inches long, bent in the form of a knee, and widened at one end, is tied over at that end with a piece of moist ox-bladder, the bladder now thoroughly dried, and the tube filled with mercury and inverted, so that the open narrow end stands in a cup of mercury, the mercury in the tube falls to about 27 inches (Hessian), and remains, if the bladder have no flow, at that height, rising and falling as the mercury does in a barometer.

No air passes through the dry bladder into the Torricellian vacuum thus produced. When, by proper manipulation, we have allowed to pass out as much as can be removed of the air still contained in the tube, we have in this arrangement a barometer, containing no more air than would be found in one made with a similar tube hermetically sealed at the wide end, provided the mercury in the latter had not been boiled in the tube to expel the last traces of air. By the desiccation of the bladder, its pores, which allowed a passage to water, brine, oil, or even mercury, have obviously been closed by the adhesion of the successive layers of membrane, which perhaps cross each other, so that the bladder is not more permeable for the particles of air than a slice of horn of the same thickness.

Experiments.

If we introduce water into the tube in the position Fig. 10, to the line marked *b*, and, after filling the narrow part of the tube with mercury, invert it in a vessel of mercury, Fig. 11, we observe a number of minute bubbles of air passing through the moist bladder into the tube. The mercury falls to a certain point, which is higher

Fig. 10.

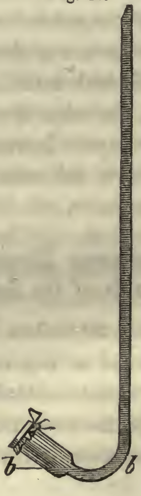
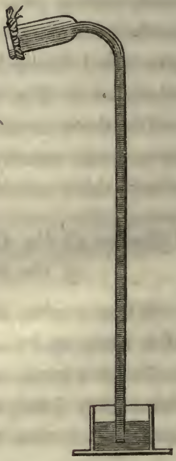


Fig. 11.



or lower according to the thickness of the bladder; it stands at a lower level with a thin membrane than with a thick one. When a single layer of ox-bladder is used, it falls to 12 inches (above the level of the mercury in the vessel); with a double layer, it stands at from 22 to 24 inches.

If we take care to allow the water standing above the mercury to enter the wide part of the tube, so that the bladder is kept at all times covered with water, the mercury remains stationary at the same level. If, for example, it stood at 12 inches, it remains there, although the quantity of water is constantly diminishing by evaporation from the bladder; and it maintains its level, even after all the water has disappeared.

The height of the mercury in the narrow tube is an exact measure of the pressure acting on the surface of the bladder. The pressure in the inside of the tube is less than the existing pressure of the atmosphere outside by the height of that column of mercury.

This difference of level between the mercury in the vessel and that in the tube is the limit of the pressure under which air passes into the water through the pores of the bladder; or under which the molecules of water in the pores are displaced by the molecules of air.

If we fill the tube entirely with water, and place the narrow end in mercury, while the wide end, closed with bladder, is exposed to the air, the mercury rises in the narrow limb, and at last reaches a point identical with that to which it fell in the preceding experiment. For each specimen of bladder, according to its thickness, the level to which the mercury reaches is of course different.

When the diameter of the wide part of the tube, which is closed with bladder, is 12 millimetres, and that of the narrow tube 1 millimetre, the mercury rises, with ox-bladder, according to the temperature and the hygrometric condition of the air, to from 22 to 65 millimetres in one hour.

The cause of the rise of the mercury in this experiment hardly requires a special explanation.

Explanation. The bladder is penetrated with water, covered on one side with water, and on the other in contact with a space (the air) not saturated with aqueous vapor. The water contained in the pores of the side of the bladder turned towards the air evaporates; the space which it had occupied in the pores is filled with successive portions of water from within, in virtue of the attraction of the substance of the pores for water. The volume of the water in the tube diminishes, and thus a vacuum arises, in which the mercury is forced to rise by the atmospheric pressure. The space formerly occupied by the water which has evaporated is now filled with mercury.

When the mercury has reached a permanent level, the external pressure, which acts on the water in the pores of the bladder (and which tends to displace the particles of water) is obviously equal, before air enters, to the attraction which the substance of the bladder has for the particles of water, and these last to each other. Were the attraction less, air would enter, and the particles of water could not maintain their position.

The rise of the mercury, or its motion towards the surface of the bladder, that is, towards the point where evaporation is going on, is the result of a difference of atmospheric pressure, determined by the evaporation of the water, or of the liquid which penetrates through the bladder, and by the absorbent power of the bladder for that liquid.

One chief condition of the efficiency of a bladder, in regard to the rise of a column of liquid, is, that it is kept constantly in contact with the liquid, for without this contact the absorbent power cannot manifest itself.

By the evaporation, a continual efflux of water, in the form of vapor, towards the side on which the air lies, is produced; and by the capillary action of the bladder on the other side, water is absorbed and retained with a force which counterpoises 12 or more inches of mercury, according to the thickness of the bladder.

Dependence upon the state of the barometer.

Now, since the rise of the mercury is an effect of the atmospheric pressure, it is plain that the height to which the mercury rises must depend to a certain degree on the state of the barometer.

In a tube, filled with water, and closed with bladder, the absorbent force of which is equal to the pressure of a column of 12 inches of mercury, the mercury rises by evaporation to the height of 12 inches, as long as a column of 12 inches of mercury can be sustained by the external atmospheric pressure. If this external pressure fall below that limit, the mercury in the evaporation tube falls to the same extent, and if there be water above the mercury, this water separates from the bladder.

This property of bladder, therefore, would appear unaltered at an elevation at which the barometer should stand at 12 inches; at a still greater elevation, on the contrary, the liquid would separate from the bladder.

The pressure of the air has no influence on the amount of evaporation.

The external pressure has no influence on the amount of the water evaporating in the pores of the bladder; that amount depends on the hygrometric state of the surrounding air, and on the temperature. In a rarefied air (provided it can take up moisture), evaporation goes on more rapidly than in a denser air; and hence it is clear, that, at certain elevations, the effect of the bladder on the level of the liquid is more quickly produced than at the level of the sea. The amount of water which evaporates is directly proportional to the surrounding space, and to the temperature and corresponding tension of the liquid.

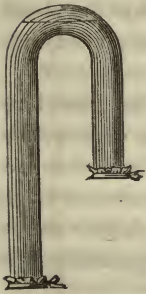
When the tube, Fig. 10, is filled with water to *b*, then entirely filled with mercury, and inverted in mercury, the mercury, as we have seen, assumes a fixed level. If now we keep the upper or wide end of the tube, which is closed with bladder, immersed in a vessel of water, Fig. 12, we shall find, after a short time, that the mercury sinks in the narrow tube. If its level has been 12 inches above that of the mercury in the vessel, it sinks when the bladder is put into water, 3 or 4 inches for example, and remains stationary at 8 or 9 inches, without sinking further for the next 12 hours. The sinking of the mercury is caused by water being forced through the bladder into the tube, in virtue of the existence of an external pressure greater than the pressure on the inside of the tube.

Fig. 12.

Permeability of bladder greater to water than to air.

To displace the aqueous particles in the pores of the bladder by other aqueous particles requires obviously a much smaller pressure than is necessary to displace them by particles of air. In the one case, where both surfaces of the bladder are in contact with the liquid, the attractive force (that of the bladder for the water and of the water for the bladder) is equal on both sides; but not so in the other case, where one side of the bladder is in contact with air. If the bladder had the same absorbent power for the particles of air as for those of water, the particles of air and water would pass through the bladder under the same pressure; the experiment shows, that the absorbent power and permeability of the bladder for air are far less than for water. Hence it comes to pass, that when, with a given portion of bladder, in the apparatus, Fig. 11, mercury is raised by evaporation to a height of 12 inches, less than 12 inches of mercury are required, in the apparatus, Fig. 1, to cause water to pass through the bladder.

Fig. 13.



Experiments on a tube closed at both ends with membrane;

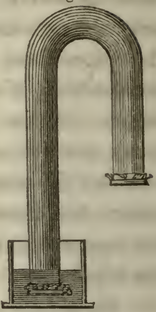
When the tube (Fig. 13) is filled with water, closed with bladder at both ends, and exposed to evaporation, the bladders in a short time become concave, that is, they are pressed inwards. As the evaporation of the water through the moist surfaces of the bladder proceeds, there is formed in the upper part of the tube a vacuum, which is filled with aqueous vapor, and which continues to increase. The place of the water which evaporates is, as in the experiments previously described, gradually occupied by air, which enters the tube through the bladder.

It is evident, that when air enters the tube (Fig. 13), the pressure on the surface of the bladder is equal to the absorbent force of that bladder for the water. In the apparatus, Fig. 11, with the same bladder, the mercury might have been raised, in consequence of the evaporation, to a height of 4, 6, 12, or more inches, according to the thickness of the membrane.

with one end in brine, the tube filled with water;

When the longer limb of the bent tube, after it has been filled with water, and closed at both ends with bladder, is placed in a vessel containing brine, and exposed to evaporate in the air, as in Fig. 14, it is plain that when the atmospheric pressure, increasing in consequence of the evaporation of the water on both the surfaces of the bladder, reaches the point at which the brine flows through the pores of the bladder, then the place of the water which evaporates is occupied by brine.

Fig. 14.



In fact, when the brine is colored blue, we observe, after a few hours, that a blue stratum forms within the tube, which constantly increases, till at last the vessel of brine is emptied, and the tube is entirely filled with brine.

with one end of the tube in bile;

with one end in oil.

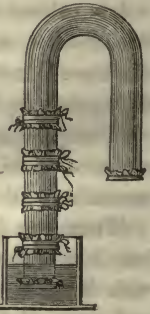
If the longer limb be immersed in bile instead of brine, the tube fills with bile, and if we employ, for closing one end, a membrane rather thinner than we use for the other, from which the evaporation takes place, and then place the end with the thinner membrane in oil (oil of marrow), the tube gradually fills with oil.

In all these cases, no air enters the tube, which continues full of liquid, as it was at first.

Effect of a series of short tubes, closed at both ends with membrane, and connected with each other.

If we connect the evaporation tube by collars of caoutchouc with short bits of tube (Fig. 15), full of water, and tied with bladder at both ends; and if we immerse the last bit of tube in brine, urine, oil, &c., all these cells, and at last the evaporation tube itself, become gradually filled with brine, urine, oil, &c.

Fig. 15.



Motion of liquid is toward the surface from which evap-

The most general expression for these experiments and results is this; — that all liquids, which are in connection with a membrane from the surface of which evaporation can take place, must acquire motion towards that membrane.

oration takes place.

The amount of this motion is directly proportional to the rapidity of evaporation, and consequently to the temperature and hygrometric state of the atmosphere.

Influence of the skin and cutaneous transpiration upon the health.

That the skin of animals, and the cutaneous transpiration, as well as the evaporation from the internal surface of the lungs, exert an important influence on the vital processes, and thereby on the state of health, has been admitted by physicians ever since medicine has existed; but no one has hitherto ascertained precisely in what way this happens.

The cutaneous evaporation has an important share in causing the motion of the animal fluids.

From what has gone before, it can hardly be doubted, that one of the most important functions of the skin consists in the share which it takes in the motion and distribution of the fluids of the body.

The surface of the body of a number of animals consists of a covering or skin permeable for liquids, from which, when, as in the case of the lung, it is in contact with the atmosphere, an evaporation of water, according to the hygrometric state and temperature of the air, constantly goes on.

If we now keep in mind, that every part of the body has to sustain the pressure of the atmosphere, and that the gaseous fluids and liquids contained in the body oppose to this pressure a perfectly equal resistance, it is clear, that, by the evaporation of the skin and lungs, and in consequence of the absorbent power of the skin for the liquid in contact with it, a difference in the pressure below the surface of the evaporating skin occurs. The external pressure increases, and in an equal degree the pressure from within towards the skin. If now the structure of the cutaneous surface does not permit a diminution of its volume, a compression (in consequence of the loss of liquid by evaporation), it is obvious that an equalization of this difference in pressure can only take place from within outwards; first from within, and especially from those parts which are in closest contact with the atmosphere, and which offer the least resistance to the action of the external pressure.

Evaporation causes the fluids of the body to move towards the skin and lungs.

Hence it follows, that the fluids of the body, in consequence of the cutaneous and pulmonary transpiration, acquire a motion towards the skin and lungs, which must be accelerated by the circulation of the blood.

Change in the laws of mixture of dissimilar liquids by evaporation.

By this evaporation, the laws of the mixture of dissimilar liquids, separated by a membrane, must be essentially modified. The passage of the food dissolved in the alimentary canal, and of the lymph into the bloodvessels, the expulsion of the nutritive fluid out of the minuter bloodvessels, the uniform distribution of these fluids in the body, the absorbent power of the membranes and skins, which, under the actual pressure, are permeable for the liquids in contact with them, are under the influence of the difference in the atmospherical pressure, which is caused by the evaporation of the fluids of the skin and lungs.

Effects of dry and moist air, and of elevation, upon the health.

The juices and fluids of the body distribute themselves, according to the thickness of the walls of the vessels, and their permeability for these fluids, uniformly through the whole body; and the influence which a residence in dry or in moist air, at great elevations or at the level of the sea, may exert on the health, in so far as the evaporation may thus be accelerated or retarded, requires no special explanation; while, on the other hand, the suppression of the cutaneous transpiration must be followed by a disturbance of this motion, in consequence of which the normal process is changed where this occurs.

The pressure urging the fluids towards the skin is equal to the difference of pressure acting on the surface of the skin.

The pressure, which, in consequence of the evaporation, urges the fluids within the body to move towards the skin, is, as may readily be understood, equal to the difference of pressure acting on the surface of the skin.

From the experiment, Fig. 13, it is plain, that when one of the two surfaces of bladder at the ends of the tube, Fig. 12, is exposed to atmospheric evaporation, while the other end is moistened with water, brine, or oil, these liquids are rapidly absorbed by the membrane, that is, are forced in by the external atmospheric pressure, and it is not less obvious, that the same thing takes place with the liquid with which one of the two evaporating surfaces has been moistened in the middle only; while the evaporation continues around the moistened spot.

If we moisten the skin, the liquids are forced in by external pressure.

If, therefore, we moisten with a liquid the surface of the evaporating skin at any point, the liquid is forced inwards by the external pressure.

Rubbed with fat, the skin ceases to transpire.

Let us suppose any part of the skin to be rubbed with fat, the transpiration ceases at that part. If now the skin around the part is in its normal activity, if, therefore, in the surrounding parts liquid is constantly passing off by evaporation, the fat must be urged, by the unequal pressure thus arising, towards these parts, or it is absorbed, just as water, in the apparatus, Fig. 12, is absorbed, when in consequence of evaporation a difference between the internal and external pressure has arisen. If the whole skin were covered with fat, the absorption would be effected by the pulmonary evaporation.

The blistering of the skin, and the sun-burning, to which men are exposed at great elevations, arise from the extraordinary dryness of the air, the increased evaporation, and the pressure by which the fluids filling the vessels are forced towards the surface.

Causes of the efflux of sweat.

Several causes contribute jointly to the appearance of the sweat,—to the efflux of fluid from the pores of the skin. One of these obviously depends on the velocity which the fluid set in motion by evaporation or by a mechanical cause acquires from the accelerated motion of the blood. In consequence of this velocity, the fluid moves out beyond the limits of the absorbing membrane or skin.

Fishes die in water because the due distribution of the fluids is prevented.

The changes of the vital process, caused by the unequal distribution of fluid in the body in consequence of evaporation, are best seen in animals which live in water, in whom, therefore, the above explained cause of motion in the normal state does not act. When a fish is held immersed in water, so that the head is out of the water, while the rest of the body is covered, it dies in a few minutes. It dies exactly in the same way when head and gills are held in the water, and the body in air (Milne Edwards); in both cases, without loss of weight. This fact shows that even if the weight of the animal be kept unaltered by the absorption of water through the body kept in that medium, yet the distribution of the fluids in the body does not take place in the proportion necessary for the preservation of their vital functions. The fish dies.

Experiments by Hales on the motion of the sap in plants.

It is hardly necessary to remind the reader, that the experiments described in the foregoing pages, in so far as they permit us to draw conclusions as to the cause of the motion of the juices of the animal body, agree in all respects with the observations made on plants by Stephen Hales more than 120 years since.

The experiments of Hales on the mechanism of the motion of the sap may stand as a pattern to all times of an excellent method. That they remain, to this moment, unsurpassed in the domain of vegetable physiology, may be perhaps explained by the fact that they date from the age of Newton. They ought to be familiar to every vegetable physiologist.

In the beginning of his work, Hales describes the experiments which he made on the motion of the sap in plants in consequence of their evaporation in branches covered with foliage, in cut plants as well as in those still provided with roots.

Influence of the pressure of a column of water, with and without the help of evaporation.

He shows by the following experiment the influence of the mechanical pressure of a column of water, with and without the help of evaporation.

To a branch of an apple-tree bearing its twigs and leaves, Hales fastened, air-tight, a tube 7 feet long. He kept the branch with its twigs and leaves immersed in a large vessel of water, and filled the tube with water. By the pressure of the column of water, water was forced into the branch, and in 2 days the water in the tube had sunk 14¼ inches.

On the third day, he took the branch out of the water, and exposed it to free evaporation in the air. The water in the tube fell, in 12 hours, 27 inches.

To compare the force with which water is driven through the vessels of the wood, by pressure alone, with that produced by pressure and evaporation, he joined an apple branch, 6 feet long, with leaves, and exposed to the air, with a tube 9 feet long, which was filled with water.

From the pressure caused by the column of water, and by the evaporation going on at the surface of the twigs and leaves, the water fell (XIth experiment), *in one hour*, 36 inches. He now cut off the branch 13 inches below the tube, and placed the portion cut off (with the twigs and leaves) vertically in a vessel of water. This last absorbed, in 30 hours, 18 ounces of water, while the portion of wood remaining in connection with the tube, which was 13 inches long, only allowed 6 ounces of water to pass, and that under the pressure of a column of 7 feet of water.

The motion of the fluids caused by the evaporating surface alone.

Hales shows, in three other experiments, that the capillary vessels of a plant, alone, and in connection with the uninjured roots, are easily filled with water by capillary attraction, without, however, possessing the power of causing the sap to flow out and to rise in a tube attached. The motion of the sap, concludes Hales, belongs to the evaporating surface alone; he proves that it goes on in an unequal degree from the stem, the twigs, the flowers, and fruit, and that the effect of the evaporation stands in a fixed ratio to the temperature and hygrometric state of the air. If the air were moist, but little was absorbed; the absorption was hardly perceptible on rainy days.

He opens the second chapter of his Statistics with the following introduction: —

"Having in the first chapter seen many proofs of the great quantities of liquor imbibed and perspired by vegetables, I propose in this, to inquire with what force they do imbibe moisture. Though vegetables (which are inanimate) have not an engine, which, by its alternate dilations and contractions, does in animals forcibly drive the blood through the arteries and veins; yet has nature wonderfully contrived other means, most powerfully to raise and keep in motion the sap."

The force with which sap is moved in plants

In his experiment XXI., he exposed one of the chief roots of a pear-tree in full growth at a depth of 2½ feet, cut off the point of it, and connected the part of the root left in connection with the stem with a tube, which he filled with water, and closed with mercury.

In consequence of the evaporation from the surface of the tree, the root absorbed the water in the tube with such a force, that in six minutes the mercury rose to 8 inches in the tube. This corresponds to a column of water 9 feet high.

This force is nearly equal to that with which the blood moves in the great femoral artery of the horse. Hales, in his experiment XXXVI., found the force of the blood in various animals: — "By tying those several animals down alive upon their backs, and then laying open the great left crural artery, where it first enters the thigh, I fixed to it (by means of two brass pipes which run one into the other) a glass tube of above 10 feet long, and ⅛th of an inch in diameter in bore. In which tube the blood of one horse rose 8 feet 3 inches, and the blood of another horse 8 feet 9 inches. The blood of a little dog, 6½ feet high."

and blood in animals.

Hales showed, by special experiments, that the absorbent force which he pointed out in the root is found also in the stem, in each separate twig, each leaf, and every part of the surface; and that the motion of the sap continues from the root towards the twigs and leaves, even when the stem has been entirely stripped of bark, inner and outer. This force acts not only from the roots in the direction of the summit, but also from the summit in the direction of the root.

From his experiments he deduces the presence of a powerful attractive force, residing in every part of the plant.

This force is atmospheric pressure.

We now know, that this attractive force, as such, did not cause the rise of the mercury or water in his tubes, and it appears clearly from his experiments, that the absorbent power of plants, of each leaf, of each fibre of the root, is sustained by a powerful external force, which is nothing else than the pressure of the atmosphere.

A partial vacuum is caused within plants by evaporation.

By the evaporation of water at the surface of plants, a vacuum arises within them, in consequence of which water and matters soluble in water are driven inwards and raised from without with facility, and this external pressure, along with capillary attraction, is the chief cause of the motion and distribution of the juices.

The sap has the power of absorbing gases.

With respect to the absorbent power of the surface of the plant for gases, under a certain external pressure, his experiments offer the most beautiful evidence. Hales says, in his experiment XXII., — "This height of the mercury did in some measure show the force with which the sap was imbibed, though not near the whole force; for while the water was imbibing, the transverse cut of the branch was covered with innumerable little hemispheres of air, and many air-bubbles issued out of the sap-vessels, which air did in part fill the tube *e r*, as the water was drawn out of it; so that the height of the mercury could only be proportionable to the excess of the quantity of water drawn off above the quantity of air which issued out of the wood. And if the quantity of air which issued from the wood into the tube had been equal to the quantity of water imbibed, then the mercury would not rise at all; because there would be no room for it in the tube. But if 9 parts in 12 of the water be imbibed by the branch, and in the mean time but three such parts of air issue into the tube, then the mercury must needs rise near 6 inches, and so proportionably in different cases."

Injury of plants lessens the absorbent power.

When, in his experiments, the root, the stem, or a twig had been injured at any part, by the cutting off of buds, root-fibres, or small twigs, the absorbent power of the remainder was diminished in a very obvious degree (because, from these places, by the entrance of air the difference of pressure was more easily equalized); the absorbent power was greatest on freshly-cut surfaces, on which, however, it gradually decreased, till, after several days, it was not greater in these places than in the uninjured surface of the plant.

The evaporation, further argues Hales, is the power-

Evaporation supplies food to the plant.

ful cause which provides food for the plant and its vicinity. Disease and death of the plant follow, when the proportion between evaporation and supply is interrupted or destroyed in any way.

When, in hot summers, the earth cannot supply, through the roots, the moisture which during the day has evaporated through the leaves and surface of the tree, when the tree, or a twig of it, dries up, the motion of the sap is arrested at these points. When once dried, capillary action alone cannot restore the original activity; the evaporation is the chief condition of the life of plants; by its means a permanent motion, a continually repeated change in the quality of the juice (sap), is effected.

Necessity of cutting off branches from a transplanted tree.

"By comparing," says Hales, "the surface of the roots of plants with the surface of the same plant above ground, we see the necessity of cutting off many branches from a transplanted tree: for if 256 square inches of root in surface were necessary to maintain this cabbage in a healthy natural state, suppose, upon digging it up, in order to transplant, half the roots be cut off (which is the case of most young transplanted trees), then it 's plain that but half the usual nourishment can be carried up, through the roots, on that account; and a very much less proportion, on account of the small hemisphere of earth the new-planted shortened roots occupy; and on account of the loose position of the new-turned earth, which touches the roots at first but in few points."

Hales proves the influence of suppressed evaporation by the following observations on hop-vines.

Observations of Hales on the blight in hops.

"Now there being 1,000 hills in an acre of hop-ground, and each hill having three poles, and each pole three vines, the number of vines will be 9,000; each of which imbibing four ounces, the sum of all the ounces imbibed in an acre in a twelve hours' day will be 36,000 ounces = 15,750,000 grains = 62,007 cubic inches, or 220 gallons; which divided by 6,272,640, the number of square inches in an acre, it will be found that the quantity of liquor perspired by all the hop-vines will be equal to an area of liquor as broad as an acre, and $\frac{1}{101}$ part of an inch deep, besides what evaporated from the earth. And this quantity of moisture in a kindly state of the air is daily carried off in a sufficient quantity to keep the hops in a healthy state; but in a rainy, moist state of air, without a due mixture of dry weather, too much moisture hovers about the hops, so as to hinder in a good measure the kindly perspiration of the leaves, whereby the stagnating sap corrupts, and breeds mouldy fen, which often spoils vast quantities of flourishing hop-grounds.

"This was the case in the year 1723, when ten or fourteen days' almost continual rains fell, about the latter half of July, after four months' dry weather; upon which the most flourishing and promising hops were all infected with mould or fen, in their leaves and fruit, whilst the then poor and unpromising hops escaped, and produced plenty; because they, being small, did not perspire so great a quantity as the others; nor did they confine the perspired vapor, so much as the large thriving vines did, in their shady thickets. This rain on the then warm earth made the grass shoot out as fast as if it were in a hot-bed; and the apples grew so precipitately, that they were of a very fleshy constitution, so as to rot more remarkably than had ever been remembered.

"The planters observe, that, when a mould or fen has once seized any part of the ground, it soon runs over the whole; and that the grass, and other herbs under the hops, are infected with it.

"Probably because the small seeds of this quick-growing mould, which soon come to maturity, are blown over the whole ground Which spreading of the seed may be the reason why some grounds are infected with fen for several years successively."

Fire-blasts in hops.

"I have in July (the season for fire-blasts, as the planters call them) seen," says Hales, "the vines in the middle of a hop-ground all scorched up, almost from one end of a large ground to the other, when a hot gleam of sunshine has come immediately after a shower of rain; at which time the vapors are often seen with the naked eye, but especially with reflecting telescopes, to ascend so plentifully, as to make a clear and distinct object become immediately very dim and tremulous. Nor was there any dry, gravelly vein in the ground, along the course of this scorch. It was therefore, probably owing to the much greater quantity of scorching vapors in the middle than outsides of the ground, and that being a denser medium, it was much hotter than a more rare medium.

"This is an effect which the gardeners about London have too often found to their cost, when they have incautiously put bell-glasses over their cauliflowers early in a frosty morning, before the dew was evaporated off them; which dew being raised by the sun's warmth, and confined within the glass, did there form a dense, transparent, scalding vapor, which burnt and killed the plants."

When these observations are translated into our present language, we perceive with what acuteness and accuracy Hales recognized the influence of evaporation on the life of plants.

Hales recognized the influence of evaporation on the life of plants.

According to him, the development and growth of the plant depends on the supply of nourishment and moisture from the soil, which is determined by a certain temperature and dryness of the atmosphere. The absorbent power of plants, the motion of their sap, depends on evaporation; the amount of food necessary for their nutrition, which is absorbed, is proportional to the amount of moisture given out (evaporated) in a given time. When the plant has taken up a maximum of moisture, and the evaporation is suppressed by a low temperature or by continued wet weather, the supply of food, the nutrition of the plant, ceases; the juices stagnate, and are altered; they now pass into a state in which they become a fertile soil for microscopic plants. When rain falls after hot weather, and is followed by great heat without wind, so that every part of the plant is surrounded by an atmosphere saturated with moisture, the cooling due to further evaporation ceases, and the plants are destroyed by fire-blast or scorching (*Sonnenbrand*, German, literally *sun-burn* or *sun-blight*).

Decaying juices of plants become a fertile soil for microscopic plants.

After the experience and observations of so long a period in reference to the influence of evaporation on the condition of plants, I hardly think that any unprejudiced observer can entertain the smallest doubt concerning the cause of the great mischief which has befallen agriculture during the last few years. If Hales, that unequalled observer and inquirer, had known the potato disease, I hardly believe that he would have ascribed it to an internal cause belonging to the plant, any more than he thought of ascribing the blight of the hop-plants, formerly mentioned, to a special hop disease, or the rotting of the apples to an apple disease. Even Parmentier, to whom France is indebted for the introduction of the potato, knew this disease, and has very accurately described it. The term "potato-rot" has been known to the oldest peasants and agriculturists since their youth; it has, doubtless, only acquired

Origin of the potato disease is probably similar to that of the blight in hops.

The potato disease long known.

of late years the frightful significance, which seems to threaten the well-being of nations, since the causes, which formerly brought it locally into existence, have spread over whole districts and countries. The writings of Hales bring to our century from a preceding one the consoling certainty (and this is especially important), that the cause of this decay is not to be looked for in a degeneration of the plant, but depends on the combination of certain conditions accidentally coincident; and that these, when they are well ascertained and kept in view, enable the agriculturist, if not to annihilate, at least to diminish, their hurtful influence.

Its great prevalence in the last few years depends on the combination of certain conditions accidentally coincident, and not on the degeneration of the plant, as a species.

The potato-plant obviously belongs to the same class of plants as the hop-plant; namely, to that class which is most seriously injured by the stagnation of their juices in consequence of suppressed transpiration. According to Knight, the tubers are not formed by swelling of the proper roots, but by the development of a kind of underground stalks or runners. He found that when the tubers under ground were suppressed, tubers were formed on the stalks above ground; and it is conceivable that every external cause which exerts a hurtful influence on the healthy condition of the leaves and stalks must act in like manner on the tubers. In the districts which were most severely visited by the so-called potato disease in 1846, damp, cold, rainy weather followed a series of very hot days; and in 1847, cold and rain came on, after continued drought, in the beginning of September, exactly at the period of the most luxuriant growth of the potatoes.

In most places, no trace of disease was observed in the early potatoes before the middle of August; and even after that period, low-lying, cold, and wet fields were chiefly attacked by it. In many plants, in the same field in which the seed potatoes had been destroyed by putrefraction and decay, the tubers appeared quite healthy, while in others it was easy to see that those tubers alone which lay next to the old potatoes were infected and attacked by the disease, and that on the side next to the old tubers.

Observations of the author.

In 1846 all the potato-plants in my garden died completely off towards the end of August, before a single tuber had been formed; and in 1847, in the same field, the tubers of all those plants which stood under trees and in protected spots were quite rotten, while no trace of disease appeared in spots which were more elevated and more fully exposed to the current of air.

The cause is the same as that which excites influenza.

The cause of the disease is the same which, in spring and autumn, excites influenza;* that is, the disease is the effect of the temperature and hygrometric state of the atmosphere, by which, in consequence of the disturbance of the normal transpiration, a check is suddenly, or for a considerable time, given to the motion of the fluids, which is one chief condition of life, and which thus becomes insufficient for the purposes of health, or even hurtful to the individual.

The whole existence of a plant, the resistance which it opposes to the action of the atmospheric oxygen, is most closely connected with the continued support of its vital functions. The mere alternation of day and night makes, in this respect, a great difference. The sinking of the external temperature by a few degrees causes the leaves to fall in autumn; and a cold night is followed by the death of many annual plants.

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* Schonbein has observed that the prevalence of influenza and the presence of ozone in the air are in proportion to each other. Is it yet to be found that there are causes influencing the quantity of this form of oxygen in the air, — causes more energetic in the last few years than hitherto? The circumstance, that ozone greatly hastens decay, adds interest to the inquiry. — E. N. H.

If we reflect that a plant, in order to protect itself from external causes of disturbance, or to seek the food which it requires, cannot change its place; that its normal vital functions depend on the simultaneous and combined action of water, of the soil, of the external temperature, and of the hygrometric state of the atmosphere; that is, on four external circumstances; it is easy to comprehend the disturbance of functions which must occur in the organism in consequence of any change in the mutual relations of so many combined agencies. The state of a plant is a sure indication of equilibrium or of misproportion in the external conditions of its life; and the dexterity of the accomplished gardener consists exactly in this, that he knows and can establish the just proportion of these conditions for each species of vegetable. Only one of these numerous conditions is in the power of the agriculturist, and that is, the production of the quality of the soil appropriate for the crop, including the necessary modification of its composition, by the mechanical working of the soil; by the irrigation or draining of his fields; and lastly, by the employment of manure. When one of the constituents of the soil, which, under the given circumstances, is necessary for the support of the vital functions, is absent, the external injurious influence is strengthened by this deficiency. Had this constituent been present, the plant would have been enabled to oppose to the external hurtful influences a continued resistance. One day may be decisive as to the life or death of a plant. An accurate knowledge of the influence exerted by the various constituents of the soil on the diseased condition must enable the agriculturist to protect and preserve many of his fields for a long time from this destruction; but it is obvious that a universal remedy against this evil does not exist.

The life of plants is dependent chiefly on four external causes,

only one of which, namely, the quality of the soil, is in the power of the agriculturist.

Effects of suppressed evaporation.

When the vessels of the plant are filled to overflowing with water, and the motion of the sap is suppressed, the nutrition, in most plants, is arrested, and death takes place. Every one knows the effect of a sudden or of a gradual overfilling of certain parts or organs, when the corresponding evaporation is suppressed. By the endosmotic pressure of the water flowing towards those cells which contain sugar, mucilage, gum, albumen, and soluble matters in general, the juicy fruits and seeds approaching maturity burst, and the juice of grapes, cherries, plums, &c., passes, on contact with the air, into a state of progressive change. The fungi which have been observed on the potato-plants, and the putrefaction of the tubers, are not the signs of a disease, but the consequences of the death of the plant.

Observations of Hales on the rise of spring sap in perennial plants.

Among the most important of the experiments made by Hales, we must reckon undoubtedly those on the rise of the spring sap in perennial plants. His observations have been entirely confirmed by all those who since his time have studied the subject; but, in my opinion, without our having approached one step nearer to the cause of the phenomena.

The most recent experiments on this subject by E. Brücke, leave no doubt in regard to the actual state of our knowledge.

Views of Dutrochet.

According to Dutrochet, it is the extremities of the radical fibres, called by De Candolle spongioles, which effect the rise of the spring sap; and he believes (L'Agent Immédiat du Mouvement Vital, Paris, 1826) that the force with which the sap is driven upwards acts from the root. Dutrochet cut off a piece of a vine-stem, two metres long; and he saw that the sap flowed steadily from the shortened stem in connection with the root. When he had again cut it off close to the ground, he observed that the portion in the ground continued to pour forth sap from the whole cut surface. He pursued the experiment, going deeper every time, and he always found that the sap flowed from the part left in the ground, till at last he came to the extreme points of the fibres, in which he then located the origin of the moving force.

The peculiar activity of the spongioles must, according to Dutrochet, be ascribed to all the causes, taken together, which determine the phenomena of Endosmosis.

Objections to these views of Dutrochet.

Now that we are better acquainted with the phenomena of what is called Endosmosis, we may oppose to this view some well-founded doubts. All observers agree, that the increase in volume of a liquid, separated from another liquid by a porous diaphragm, is determined by a difference in the qualities of the two liquids. If their composition and properties be the same, there is no cause sufficient to produce mixture and change of volume, since in this case the attraction of both for the diaphragm and for each other is perfectly equal.

Observation of Brücke on the specific gravity of spring sap in vines.

In the course of his admirable researches, Brücke determined the specific gravity of the spring sap which had flowed from the vine. He found it, in one plant, = 1.0008, and in another, = 1.0009.*

These numbers prove irresistibly, that the specific gravity of the sap of the vine is in no way different from that of ordinary spring water, or of the water which has filtered through garden mould. In most cases, spring water contains even more dissolved matter.

The spring sap of the vine which had the sp. g. 1.0008 raised a column of mercury to the height of 174 lines (14.5 inches), and therefore exerted a press-

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* Poggendorf's Annalen der Physik, LXIII. 177.

ure equal to that of a column of water 195 inches high. It is quite impossible to account for this pressure by the difference in the amount of dissolved matter in the water absorbed by the roots, and the sap flowing from the cut surface. In the experiment No. IX. of Brücke, made with a vine the sap of which had the sp. g. 1.0009, the mercury was raised at 7 A. M. to the height of 209 lines (nearly 17.5 inches).

No one can doubt that what is called Endosmosis has some share in the rise of the sap of the maple and birch trees, which is proportionally rich in sugar, and differs materially in composition from spring water, as well as on the flow or exudation of gummy or saccharine juices; but the pressure exerted in these cases cannot be compared to that exerted by the sap of the vine, where the causes included under the word Endosmosis cannot act.

The cause of the rise of the spring sap must be transient.

It is evident, that the cause of the pressure of the spring sap must be transient, called into action by external causes, and limited to a short period. The experiment of Dutrochet, from which he concludes that the cause of the rise of the sap resides in the extreme points of the roots, may be thus interpreted: — "The cause of the efflux and pressure of the sap exists in all parts of the uninjured plant, down to the extreme spongioles of the root."

The present season does not admit of experiments on this point; but as spring approaches, it may be proper here to develop more clearly the grounds of the opinion, that the cause of the efflux of the sap of the vine is a transient one. Perhaps some one may thus be induced to decide experimentally all the questions connected with this remarkable phenomenon.

Experiments of Hales.

Hales, in his experiment XXXIV., cut off a vine-stem 7 feet above the ground, and attached to the trunk tubes of 7 feet long, joined together. Below the cut there were no branches. This was done on the 30th of March, at 3 P. M.

As the stem poured out no sap on that day, he poured water into the attached tube to the height of two feet.

This water was absorbed by the stem, so that at about 8 P. M. the water had fallen to 3 inches in the tube.

The next day, at ½ past 6 A. M., the sap stood three inches higher than at 8 the evening before. From this time the sap continued to rise, till it reached a height of 21 feet. It would perhaps, says Hales, have risen higher, had the joinings of the tubes been more water tight.

Whatever opinion we may entertain as to the cause of the efflux and pressure of the sap, it is impossible to suppose that the mechanical or any other structure or quality of the radical fibres, the spongioles, or the inner parts of the vine-stem generally, can have changed so much between the evening of the 30th and the morning of the 31st as to give rise to two completely opposite influences.

The cause of the motion of the sap exists not merely in the spongioles, but in all parts of the plant.

On the evening of the 30th, the water poured into the tube was absorbed; on the 31st, it was expelled with a continually increasing force.

In his experiment XXXVII., Hales fixed, on three branches of a horizontally trained espalier vine, siphon tubes, filled to a certain point with mercury.

The three branches received their sap from the common stem, that stem from the root. The first branch was 7 feet from the second, the second 22 feet 8 inches from the third. The first and third branches were two years old, the middle one was older.

From the 4th to the 20th of April, the mercury stood, in consequence of the pressure of the sap, higher in the open limb of the tubes than in the other, which was attached to the branch.

The greatest height attained by the mercury was from 21 to 26 inches.

On the 21st of April, when the flowering was nearly over, the sap in the middle branch went backwards; it was absorbed, and so considerably, that the mercury stood 4 inches lower in the open limb than in the other. After a rainy night, on the 24th of April, the sap again rose in the open tube 4 inches.

In the first (lowest) branch, the sap went back on the 29th of April, 9 days after the middle one; the third (highest) branch only began to absorb the sap on the 3d of May, 13 days after the middle one.

Conclusions deduced by Hales.

We see from this experiment, as Hales observes,—"That the cause which produces the flow of the sap does not proceed from the root alone, but that it belongs to a force inherent in the stem and branches. For the middle branch followed more rapidly the changes of temperature, of dryness and of moisture, than the two others, and absorbed the sap nine days before one, and thirteen days before the other, both of which, during this time, poured out sap instead of absorbing it. (The cause of the efflux and pressure had, in the older branch, disappeared, and given place to an opposite influence, while it still continued active in the two younger branches.)

"The middle branch was 3 feet 8 inches higher than that next the stem. The height of the mercury in the three tubes was, respectively, 14½, 12½, and 13 inches. The maximum was 21, 26, and 26 inches. These numbers prove that the greater length of the middle branch had no perceptible influence on the height of the mercury, as compared with that in the other tube."

Effects of cold winds on the motion of the sap.

In his experiment XXXVIII., Hales observes,—"Moisture and warmth made the sap most vigorous. If the beginning or middle of the bleeding season, being very kindly, had made the motion of the sap vigorous, that vigor would immediately be greatly abated by cold easterly winds.*

"If in the morning, while the sap is in a rising state, there was a cold wind with a mixture of sunshine and cloud, when the sun was clouded, the sap would immediately visibly subside, at the rate of an inch in a minute for several inches, if the sun continued so long clouded; but as soon as the sunbeams broke out again, the sap would immediately return to its then rising state, just as any liquor in a thermometer rises and falls with the alternacies of heat and cold; whence it is probable, that the plentiful rise of the sap in the vine in the bleeding season is effected in the same manner."

If we consider that the sap in spring, even with a clouded sky, does not cease to rise and flow, for this even goes on during the night, we cannot explain the fall of the sap from the moment that the sun was covered by a cloud by a mere change of temperature in the juice, because the time was too short for the cooling and contraction by cooling (one inch in a minute), Heat determined the more rapid rise, and cold the fall; but they acted on a cause which lay higher than the

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* The influence of cold easterly winds, producing what is called blight upon apple-trees, is well known about the eastern extreme of Long Island. The explanation with the views here expounded is simple. The vigorous development of the tree depends upon the supply of nutriment from the soil. This requires ascent of the sap. This ascent requires evaporation from the leaves. The evaporation depends upon the capacity of the atmosphere to take up moisture. The dryer winds from the west will promote the evaporation, while those from off the sea, laden with moisture and protracted through several days, will impede it. The shrinking of the leaves, an evidence of deficient nourishment, follows. — E. N. H.

root, and which was more sensitive to heat than the liquid itself.

Hales says, in his experiment XXXVIII., — "In very hot weather many air-bubbles would rise, so as to make a froth an inch deep on the top of the sap in the tube.

"I fixed a small air-pump to the top of a long tube, which had twelve feet height of sap in it; when I pumped, great plenty of bubbles arose, though the sap did not rise, but fell a little, after I had done pumping."

In his experiments on the amount of air absorbed by plants, chapter V., he observes, "in the experiments on vines, the very great quantity of air which was continually ascending from the vines, through the sap in the tubes; which manifestly shows what plenty of it is taken in by vegetables, and is perspired off with the sap through the leaves."

When we take these facts into consideration, the opinion appears not untenable, that the incomprehensible force which causes the sap of the vine to flow in spring may be simply referred to a disengagement of gas which takes place in the capillary vessels (filled with liquid, and keeping themselves constantly full), in consequence of a kind of germination; and it is possible that the height of the column of mercury, or of water, is only a measure of the elasticity of the disengaged gas.

Gas is given off by the sap.

Let us suppose a strong glass bottle, in the mouth of which a long tube, open at both ends, and reaching to the bottom, is cemented, to be filled with a liquid in which, from any cause, a gas is disengaged (solution of sugar mixed with yeast, for example); it is evident that the liquid must rise in the tube from the separation of the gas. When it has risen to 32 feet, the gas will occupy only the half, and at 64 feet, one third, of its volume under the usual atmospheric pressure. In this case, the height of the liquid in the tube is no measure of a special power residing in the walls of the vessel; it only shows the tension of the gas.

If the walls of the vessel were permeable to the gas, under a certain pressure, no further rise, beyond that point, could occur.

If in the apparatus, Fig. 4, we push the tube *a* through the cork down to the little lead drop; if we then fill the tube *c* with water to which some yeast has been added, and *a* with solution of sugar, and expose the whole to a temperature of from 68° to 75°, the liquid rises in *b*, from the gas disengaged in *c*, very rapidly, so as to overflow. If *c* be filled with solution of sugar, and *a* with yeast, the same rise occurs, and lasts till the disengaged gas puts an end to the contact between the membrane and the liquid.

Gas is probably carbonic acid gas.

It is hardly necessary to point out, that the idea above expressed, as to the cause of the flow and pressure of the spring sap, is nothing more than an indication of the direction in which experiments must be made. When we know with accuracy the volume of the liquid which flows out of a vine at the time of flowering, and the quantity of gas which is developed at the same time, we shall, I trust, find ourselves a step nearer to the explanation of this phenomenon. According to the experiments of Geiger and Proust, the sap of the vine is rich in carbonic acid; and it is possible that the gas which is disengaged may be no other than carbonic acid gas.

APPENDIX.

A. — (p. 22.)

The suggestion in the editor's paper upon Glycocoll, that organized bodies are composed of lesser, already distinctly formed groups, has met with strong support in an elaborate investigation by Dr. Guckelberger,* Assistant in the Giessen Laboratory. M. Schlieper had studied with care the products of decomposition of gelatine by chromic acid. Dr. Guckelberger treated caseine, albumen, and fibrine both by manganese and chromic acid, and found that, except in relative quantities, the products of decomposition were the same or greatly alike in all.

Now, as Dr. G. has aptly remarked, there being no essential difference in the nature of the products yielded by the oxidation with manganese from those yielded by oxidation with chromic acid, notwithstanding these agents hold oxygen with unequal degrees of affinity, it follows that it is the *presence* of oxygen, not its *quantity*, that determines the character of the bodies produced. The oxygen serves to separate bodies, already formed, from each other's embrace. It removes a cement that held the members of a structure together.

The following bodies were obtained by Dr. Guckel-

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* Liebig's Annalen, LXIV. p. 39.

berger in the distillate from caseine, black oxide of manganese, and sulphuric acid : —

1. Aldehyde of acetic acid,	$C_5 H_3 O, HO$
2. Aldehyde of metacetonic acid,	$C_6 H_5 O, HO$
3. Aldehyde of butyric acid,	$C_5 H_3 O, HO$
4. Oil of bitter almonds,	$C_{14} H_5 O_2, H$
5. Formic acid,	$C_2 H O_3, HO$
6. Acetic acid,	$C_4 H_3 O_3, HO$
7. Metacetonic acid,	$C_6 H_5 O_3, HO$
8. Butyric acid,	$C_8 H_7 O_3, HO$
9. Valerianic acid,	$C_{10} H_9 O_3, HO$
10. Caproic acid,	$C_{12} H_{11} O_3, HO$
11. Benzoic acid,	$C_{14} H_5 O_3, HO$

The following bodies were obtained on decomposing caseine with chromate of potash and sulphuric acid : —

1. Aldehyde of metacetonic acid,	$C_6 H^5 O, HO$
2. Oil of bitter almonds (in small quantity),	$C_{14} H_5 O_2, H$
3. Formic acid (in small quantity),	$C_2 H O_3, HO$
4. Acetic acid,	$C_4 H_3 O_3, HO$
5. Butyric acid,	$C_8 H_7 O_3, HO$
6. Valerianic acid,	$C_{10} H_9 O_3, HO$
7. Benzoic acid (with traces of caproic acid).	
8. Benzoic acid,	$C_{14} H_5 O_3, HO$
9. Prussic acid,	$C_2 N H,$
10. Valeronitrile,	$C_{10} H_9 N,$
11. A heavy oil with the odor of cinnamon.	
12. Metacetonic acid,	$C_6 H_5 O^3, HO$

EBEN N. HORSFORD.

B.

ON THE NATURE AND PREVENTION OF THE POTATO DISEASE.

After the preceding pages were in print, I received from Baron Liebig a copy of the Journal of the Agricultural Association of the Grand Duchy of Hesse (Darmstadt), No. 7, dated 15th February, 1848, containing the account of a method proposed by Dr. Klotzsch (Keeper of the Royal Herbarium, Berlin, and a distinguished botanist and vegetable physiologist), for preventing the ravages of the potato disease. The proposal of Dr. Klotzsch, and his views as to the nature of the disease, are such as materially to strengthen the opinions expressed on this subject by Baron Liebig (see pp. 198, seq.). As a knowledge of the method suggested by Dr. Klotzsch is likely to be interesting to many of the readers of this work, I have thought it right to give it in an Appendix.

William Gregory.

Method proposed by Dr. Klotzsch for the Protection of the Potato Plant against Diseases.

" The potato, which is an annual plant, represents, in the tubers developed from the stem, the perennial part of a plant. For while the duration of its development is analogous to that of annuals, its actions coincide exactly with those of dicotyledonous shrubs and trees.

" The potato plant differs from all those plants which are cultivated for economical purposes in Europe, and can only be compared to those orchidious plants which yield salep, and which are not yet cultivated among us.

" The tubers, both of the potato and of the salep plants, are nutricious, and agree in this, that in the cells of the tubers, grains of starch, with more or less azotized mucilage, are collected, while the cell walls possess the remarkable property of swelling up into a jelly, and thus becoming easily digestible when boiled with water.

" But while the tuber of salep contains only one bud, or germ, the potato usually develops several, even many, germs.

" The potato plant, like all annuals, exerts its chief efforts in developing flowers and fruit. Like all annuals, too, it has the power of shortening this period of development, when the power of the roots is limited; as also of lengthening it when the extent and power of the roots are increased.

" We observe in nature, that plants with feebly developed roots often have a weak, sickly aspect, but yet come to maturity in flower and fruit sooner than stronger individuals, well furnished with roots.

" In perennial plants, we observe a second effort, which is directed towards preparing and storing all nutritious matter, for the consumption of the plant. The preparation of this nutriment is effected by the physiological action of the leaves, under the influence of the roots. The stronger and larger the former are, the more is this preparation of food delayed.

" The nutritious matters are stored in the colored stratum of the bark in shrubs and trees, and in the tubers in the potato and salep plants. Not only, however, the nutrient matters, but also the cells, owe their origin to the physiological action of the leaves.

" On considering these things, it follows that the potato plant requires more care than is usually devoted to it. Hitherto the whole cultivation has consisted in clearing off weeds, and hoeing up the earth round the stems. Both of these measures are indeed necessary, but they are not alone sufficient; for the plant is cultivated, not on account of its fruit, but for the sake of its tubers, and the treatment should be modified accordingly.

"The chief points to be attended to, with a view to the attainment of the object, namely, the increase of tubers, are, —

"1. To increase the power in the roots; and,

"2. To check the transformation which occurs in the leaf.

"We obtain both ends simultaneously, if, in the 5th, 6th, and 7th week after setting the tubers, and in the 4th and 5th week after planting out germs furnished with roots, or at a time when the plants reach the height of six to nine inches above the soil, we pinch off the extreme points of the branches or twigs to the extent of half an inch downwards,* and repeat this on every branch or twig in the 10th and 11th week, no matter at what time of day.

"The consequence of this check to the development of the stem and branches is a stimulus to the nutrient matters in the plant in the direction of the increase both of roots and of the multiplication of the branches of the stem above ground, which not only favors the power of the root, but also strengthens the leaves and stalks to such a degree, that the matters prepared by the physiological action of these parts are increased and applied to the formation of tubers, while at the same time the direct action of the sun's rays on the soil is prevented by the thick foliage, and thus the

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* Any one would be bitterly disappointed, who, on the principle that "there cannot be too much of a good thing," should take off more than is here recommended, in order to use it as fodder.

drying up of the soil and its injurious consequences are avoided.

"The checking of the transformation in the leaf is equivalent to the interruption of the natural change of the leaves into calyces, corollæ, stamens, and pistils, which is effected at the expense of the nutrient matters collected in the plant; and these, when this modification of the leaves is arrested, are turned to account in the formation of tubers.

"Led by these views, I made, in 1846, experiments on single potato plants, carefully marked, by pinching off the ends of the branches. They were so readily distinguished in their subsequent growth from the plants beside them, by more numerous branches, larger and darker foliage, that in truth no marking was necessary.

"The produce from these plants of tubers was abundant, and the tubers were perfectly healthy; while the plants next them which had not been so treated, gave uniformly a less produce, at the same time the tubers were rough on the surface, and in many instances attacked with the prevailing disease. This experiment was incomplete, and did not give a positive result, but it was yet encouraging for me.

"In the middle of April, 1847, an experiment was made on a low-lying field with the round white potatoes generally cultivated here, a variety which had not suffered much from the disease which first appeared here in 1845. The potatoes were planted in the usual way, by an experienced farm servant.

"After weeding them in the end of May, I renewed my experiment by pinching off the points of the branches of every second row, and repeated this in the end of June. The result surpassed all expectations. The stalks of the plants not treated on my plan were long, straggling, and sparingly furnished with leaves, the leaves themselves small and pale green.

"In the next field, potatoes of the same variety were planted on the same day, and left to nature. They appeared in the first six weeks healthy, even strong, but gradually acquired a poor aspect as the time of flowering and fruit approached, and finally exhibited precisely the same appearances as the rows not treated by pinching off the extremities in the field in which my experiments were made.

"The harvest began in the surrounding fields in the middle of August, and was very middling. The tubers were throughout smaller than usual, very scabby, and, within these fields, to a small extent, attacked by the wet rot.

"In the end of August, the difference between the rows treated by me and those not treated became so striking, that it astonished all the work-people in the neighbourhood, who were never tired of inquiring the cause. The stalks of the rows left to themselves were all now partly dried, partly dead. On the contrary, the rows treated as above were luxuriant and in full vigor, the plants bushy, the foliage thick, the leaves large and dark green, so that most people supposed they had been later planted.

"But the difference in the tubers was also very decided. The tubers of the plants in the rows treated on my plan were not indeed larger, but vastly more numerous, and they were neither scabby nor affected with any disease whatever. A few had pushed (which was to be ascribed to a late rain), and were apparently incompletely developed, while scab and wet rot attacked more and more the tubers of the other plants, which also fell off on the slightest handling.

"Although I am far from believing that I am able to explain the nature of the potato disease which has visited us of late years, yet I feel certain that I have discovered a means of strengthening the potato plant to such a degree as to enable it to resist the influences which determine such diseases.

"Should any one be deterred from continuing the cultivation of potatoes on account of the manipulation here recommended, which may be performed by women and even by children, I would remind him that the same field planted with potatoes is capable of supplying food to twice as many persons as when employed to grow wheat." — (*From the Annals of Agriculture in Prussia, edited by the College of Rural Economy.*)

Dr. Klotzsch presented to the king of Prussia a memorial, offering to give to the world his method of preventing disease in potatoes, provided he were assured of a remuneration of 2,000 dollars (about $ 1,400), if, after three years' experience, it should be found efficacious.

The king handed the memorial to the Minister of the Interior, who requested the College of Rural Economy to discuss the matter with Dr. Klotzsch.

The president of the College undertook the arrangement, and, after Dr. Klotzsch had explained to him privately his method, reported most favorably of it to the College, which unanimously recommended that the very moderate remuneration asked for by Dr. Klotzsch should be secured to him on the following conditions, which were accepted by him.

1. That the College of Rural Economy should be the judges of the efficacy of the proposed method.

2. That their decision should be given, at latest, within three years, provided the potato disease, against which the plants are to be protected, should appear during that period.

The Minister of the Interior approved of the recommendation, and authorized the College to conclude an agreement with Dr. Klotzsch.

The agreement has been concluded, and now the method is published, that it may be tried and tested as widely as possible by comparative experiments, similar to those made by Dr. Klotzsch himself. The cost of it is stated not to exceed 35 cents per acre in Germany.

It is very desirable that this method should be tried in the British islands, and as the season for trying it now approaches, I have here given Dr. Klotzsch's account entire.

William Gregory.

THE END.