An inaugural dissertation, on the phoenomena, causes and effects of fermentation : submitted to the examination of the Revd. William Smith, S.T.P. provost ; the trustees and medical professors, of the College of Philadelphia ; for the degree of Doctor of Medicine ; on the second day of June A.D. 1790 / by John Penington of Philadelphia.

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AN

INAUGURAL DISSERTATION,

ON THE

PHOENOMENA, CAUSES AND EFFECTS

OF

FERMENTATION;

SUBMITTED TO THE EXAMINATION

OF THE

REVD. WILLIAM SMITH, S. T. P. PROVOST;

THE

TRUSTEES AND MEDICAL PROFESSORS,

OF THE

COLLEGE OF PHILADELPHIA;

FOR THE DEGREE OF DOCTOR OF MEDICINE;

ON THE SECOND DAY OF JUNE A. D. 1790.

BY JOHN PENINGTON

OF PHILADELPHIA.

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the Compliments of the
Author —.

TO

THE HONORABLE

FRANCIS HOPKINSON ESQ.

JUDGE OF THE DISTRICT COURT

OF THE

UNITED STATES,

FOR THE STATE OF

PENNSYLVANIA,

MEMBER OF THE AMERICAN PHILOSOPHICAL

SOCIETY *&c. &c. &c.*

This DISSERTATION

IS WITH THE

GREATEST RESPECT

INSCRIBED,

BY

HIS MUCH OBLIGED FRIEND,

THE AUTHOR.

Philadelphia, May 24th. 1790.

INTRODUCTION.

THE rules of the college of Philadelphia, reſpecting a medical education, have, among other things made it neceſſary, that the candidate for the degree of DOCTOR OF MEDICINE ſhall produce a "Theſis, written in the Latin or Engliſh language, at his own option". As it has been the cuſtom in moſt colleges, to write medical diſſertations in the Latin language, I hope it will not appear *affectedly* ſingular to chooſe the Engliſh language as the vehicle of mine. I have no right to expect, from its contents, that it will ever be read in any country, where the Engliſh language is not perfectly underſtood. Beſides, the nature of my ſubject made it neceſſary to uſe *terms* which I did not think myſelf authoriſed to convert into an *imitation* of *Latin*. If I have erred in adopting the Engliſh language as the medium for communicating my opinions to the world, I hope the authority of Dr. Franklin, Mr. Hopkinſon, Dr. Ruſh and many other gentlemen of abilities in the United States, in favour of a perference of a modern language for a modern publication, will ſcreen me from cenſure.

FERMENTATION.

THERE are perhaps few proceſſes, or phoenomena, that fall under the obſervation of chemical enquirers, that are ſo little underſtood as the ſubject of the preſent eſſay. This want of certainty, we ſhould ſuſpect, aroſe more from the difficulty, than from the want of opportunities, for inveſtigating the ſubject, becauſe the materials for experiments are not only in every one's power to obtain, but the proceſs is almoſt daily obtruding itſelf upon us. The chief obſtacle to our advancement, in the knowledge of the cauſes and effects of fermentation, is that we reſt ſatisfied with explanations handed to us by others. The ſubject appears to be of much importance, both as a curious chemical proceſs, and as it reſpects the economical arts, and the art of medicine, and for that reaſon I have choſen it for the ſubject of the preſent diſſertation. There are many difficulties attending the inveſtigation, as every chemiſt muſt confeſs, and I may perhaps aſſign the ſame reaſon for thoſe difficulties that Mr. Henry of Mancheſter did, when treating of the ſame ſubject, that " the obſcurity and intricacy of the path, on which I am entering, the almoſt total want of guides and *my inadequate abilities* to clear away the obſtacles, throw light on the dark parts, and point out thoſe which may be traverſed with eaſe and certainty,

place me in a ſituation *truly difficult*". Theſe reaſons being applicable to me, in all their force, I hope for candor and liberality, whenever I may be found to ſtep aſide, from the common and received opinions of chemiſts, reſpecting fermentation. Some new opinions will be found in this diſſertation, but as the ſubject will admit of elucidation from experiment and as it would be wrong to admit any thing as a fact, without having aſcertained it to be ſo, I have introduced ſome experiments to prove acknowleged facts.

In handling this ſubject, I ſhall arrange it under different ſections.

Section I. I ſhall conſider the definition of fermentation, the Subſtances capable of it--and its Phoenomena.

II. I ſhall attempt an explanation of the Phoenomena attending the fermentation of vegetable ſubſtances.

III. I ſhall mention the products of fermentation.

IV. I ſhall diſtinguiſh between a mere eſcape of air and a true fermentation.

V. I ſhall mention the principal Zymics and Antizymics. And,

VI. I ſhall deliver ſome analyſis of animal matter; the difference between animal and vegetable fermentation.

SECTION I.

Definition of fermentation---Subſtances capable of i

FERMENTATION is a peculiar proce which certain parts of *dead* animal and veg etable ſubſtances are diſpoſed to undergo, when

combined with moiſture, expoſed to a degree of heat between 50 and 120 of Fahrenheit's thermometer, and in contact with air fit for combuſtion and animal reſpiration. The phenomena attending the proceſs are.

1. That the fermenting maſs becomes conſiderably warmer than the atmoſphere around it.

2. It emits a large quantity of a fluid, permanently elaſtic, accompanied with an inteſtine motion, and

3. There is always a remarkable change and alteration in the *ſenſible and chemical qualities* of all bodies that have actually fermented. We have here confined our definition to animal and vegetable ſubſtances, but we have great reaſon to believe, that ſeveral mineral mixtures will undergo ſpontaneous changes, perfectly analogous to fermentation; the gradual decompoſition of the natural pyrites, and the changes which take place in an artificial mixture of the flowers of ſulphur and iron filings, ſeem to depend upon the ſame cauſes, and are really attended with the ſame phenomena; we have alſo taken *dead* animal and vegetable ſubſtances only into our definition; this may not perhaps be quite accurate; it is probable that animals, while alive and in health, have certain parts in them that are conſtantly putrifying or fermenting, and it is poſſible that the ſame thing happens in plants, but it is probable that theſe living machines have a power of expelling theſe putrid parts, as being incompatible with their own health, beſides we find in particular diſeaſes, eſpecially in the order of *Exanthemata*, that a ſmall quantity of a diſeaſed

fluid has a power of *aſſimilating* a conſiderable part of the fluids of another animal; as for inſtance, in the ſmall-pox, in which Doctor Cullen allows that a fermentation goes on in the body; for, ſpeaking of the quantity of variolous matter, abſorbed by common infection, he ſays, "altho' it were larger than that thrown in by innoculation, it is not aſcertained that the circumſtance of quantity would have any effect. A certain quantity of *ferment* is neceſſary to excite *fermentation* in a given maſs, but that quantity given, the fermentation and aſſimilation are extended to the *whole* maſs." But this kind of fermentation, which occurs in the living animal body, cannot be examined here, for it is ſo connected with life (a principle which we do not well underſtand) that we can by no means imitate it in the dead body; it is probable that the contagious matter acts upon the animal as an animated *machine*, as well as *matter*, and that this action modifies its effects; it is alſo a ſubject of great curioſity both to the Phyſiologiſt and to the Chemiſt, that the blood of a patient, labouring under the ſmall-pox, cannot communicate the diſeaſe to another by innoculation, and it muſt certainly be very difficult to a *Chemiſt* to conceive, why after the fluids of an animal have been once fermented by the variolous matter, that the fluids of the ſame animal ſhall never take on that fermentation again, altho' they muſt have been changed twenty times or more in the courſe of life.

Moisture ſeems to be an indiſpenſible requiſite in the proceſs; the moſt putreſcent and fermentable ſubſtances we are acquainted with remain unchanged as long as they are kept dry;

ſugar is perhaps the only part in all vegetables capable of fermenting, and it is notorious that it may be kept for many years, and perhaps for ages unchanged, and the practice of the Indians in merely drying their *veniſon*, in order to preſerve it, proves that the ſame thing is true reſpecting *animal* ſubſtances.

HEAT accumulated in a ſenſible ſtate, to a certain degree, ſeems alſo indiſpenſible, and a leſs degree than the loweſt we have aſſigned abſolutely prevents fermentation. A quantity of of ſugar and water which would have completely fermented in 24 hours, in an heat of 90° was kept unfermented from November laſt, until the middle of February, although the thermometer for many days together, in that time ſtood between 50° and 60°.

The preſence of *pure air*, fit for ſupporting animal life and reſpiration, is ſo eſſential to fermentation, that without it, it cannot be excited; this opinion is generally admitted by chemiſts, and perhaps may be founded upon the experiments made by the air-pump. Natural philoſophy teaches us, that certain fruits can be preſerved in a *vacuum* for a long time, without becoming acid; but this is an entire *abſtraction* of air: however, we find that the preſence of air, unleſs that air be *pure*, is not ſufficient to excite fermentation. I believe ſeveral experiments have been made by others upon the ſame ſubject, but it may not be improper to relate two made by myſelf.

Experiment Firſt.

Part of a mixture of ſugar and water, which

was very fermentable, was confined in a jar of *inflamable air*, obtained from iron-filings and diluted vitriolic acid, and ſet ſo near a ſtove as to vary between 80 and 90 of Fahrenheit, for thirteen or fourteen hours of the twenty-four, the other part was ſet along ſide of it; in this open veſſel fermentation went on as uſual: in one week's time it had become highly acid; in the jar fermentation had not gone on, but the fluid was perfectly ſweet and unchanged.

Experiment Second.

The ſecond experiment was with animal ſubſtances; I confined a dead wild pigeon in a glaſs jar of inflamable air, in the ſame manner as in the other experiment; another was left in a large bowl, with ſome water in it, and expoſed to the heat and air in the room: in about ten days the animal thus expoſed was ſo offenſive to the ſmell, that I diſcontinued the experiments; at the ſame time the animal in the jar was ſcarce tainted in the leaſt, it was however *ſomewhat* putrid, and had a *greeniſh* appearance; but I think thoſe effects may be fairly attributed to the ſmall quantity of common air confined in the cavity of the pigion's body, which *at that time* I did know how to extricate from it.

We are neceſſarily inclined to enquire what is the nature of the fermentable materials which characteriſe bodies? and whether there is any one ſimple principle in them that is the cauſe of that change being effected in certain bodies? we ſee but one character in common with them all, they are all *inflamable*, but the cauſe of their inflamability cannot be the cauſe of their fermenta-

tion, for all inflamable bodies are not fermentable. In vegetables we believe that none of them are fermentable, unleſs they contain the ſaccharine principle, and I think it can be demonſtrated, that the products of all vegetable fermentation are the ſame. What is the fermentable principle in animal ſubſtances, or what parts are more ſuſceptible of this change than the others, is yet involved in great obſcurity, and we ſhall attempt to throw ſome light upon it in ſection ſixth; at preſent we ſhall only in general remark, that the moſt inflamable and ſoluble animal ſubſtances are the eaſieſt to ferment, or to *putrify*, as we ſay, when the term is to be applied to animals.

SECTION II.

Explanation of the Phenomena attending the Fermentation of Vegetable Subſtances.

HEAT, or a degree of it greater than that of the atmoſphere, around the fermenting maſs, is an uniform circumſtance attending fermentation; the increaſe of temperature, in my experiments however, has ſeldom been more than 10 or 12 degrees. When we reflect that all putreſcent and fermentable ſubſtances are inflamable, and during fermentation generate heat, we are immediately ſtruck with its analogy to combuſtion; here let us enquire, whether the opinion of natural philoſophers reſpecting heat is well founded. They ſuppoſe that all heat depends upon motion, and that the heat produced in combuſtion and fermentation is owing to the ſudden deſtruction of the attraction of coheſion of the particles of the body burnt or fermented.

In the firſt place, I think we have no evidence that heat and motion are the ſame thing.

2*d*. Although neither heat, nor even *cold*, nor any thing elſe, can be produced without motion, yet all motion will not produce heat: for inſtance, mercury may be agitated in a phial for ſeveral hours, without producing an increaſe of one degree of heat, and the ſea itſelf, altho' moſt violently agitated, is ſtill cold.

3*d*. The quantity of heat generated by motion, is never in proportion to the rapidity of the deſtruction of the attraction of coheſion, as we ſee when *ſalts* are diſſolved in water; (for ſolution is ſaid to be owing to the ſame cauſe;) for example, *nitre*, when finely powdered, diſſolves very rapidly, and muſt of conſequence be attended with *great motion*, but we are ſo far from generating heat, that the mixture becomes colder than the air, as we find by its ſinking the mercury in the thermometer.

4*th*. Sugar diſſolves very rapidly in water, but without producing any heat, although at the inſtant of ſolution there muſt have been both *motion*, and the deſtruction of the attraction of coheſion. If the mixture is ſuffered to ſtand, it will ferment and *generate heat*, even when there is no attraction of coheſion to overcome, that we can be ſenſible of.

The heat occurring in fermentation muſt, I think, be explained upon the theory of Doctor Black, reſpecting latent heat: it ſeems probable, that *heat* is a body, or fluid, *ſui generis*, inherent in all matter, and eſſential to its exiſtence; that

it enters into different bodies, in different proportions, as an ingredient in their compoſition, in the ſame manner as electricity is ſuppoſed to exiſt in iron in contact with the earth; whilſt a certain quantity of heat is attached to all bodies, and if I may be allowed the expreſſion, *mechanically mixed with them*, in contradiſtinction to the other mode of union of heat with bodies, which is then chemically combined with them, or is in a *latent* ſtate. When the heat is in this ſtate, it is called *ſenſible heat*; becauſe it is capable of exciting a certain ſenſation, of raiſing the mercury in the thermometer, and it is governable by certain laws, by this time pretty well aſcertained.

When heat enters into bodies as a principle, it is moſt probably in different quantities in different bodies, and it is very remarkable, that a change in the common chemical qualities of bodies alters very much the capacity of bodies to contain heat as a principle, or in a latent ſtate; hence it happens, that in almoſt all our chemical proceſſes, an alteration of temperature takes place. In fermentation, we ſuppoſe that the inflamable part or principle of the fermenting body, has a tendency to combine with *pure air*, and we ſhall juſt remark in this place, that the combuſtibility of all bodies, is by *ſome* chemiſts ſuppoſed to be owing to one homogeneous principle called the *principle of inflamability or phlogiſton*; this theory has had very powerful opponents, but I think we have reaſon to believe, that with certain modifications, it is true; and it is moſt probable that this principle is inflamable air. It is alſo known, from direct experiments, particularly of Dr. Prieſtly and Mr. Kirwan, that pure air

and inflamable air form what Doctor Black calls *fixed air*, and Mr. Bergman the aerial acid, which is preciſely the ſame elaſtic fluid thrown out in fermentation. The pure air we may juſtly ſuppoſe was derived from that great ſource the atmoſphere, and for ſeveral reaſons we may conclude, that the inflamable air was furniſhed by the fermenting vegetable, but we by no means ſuppoſe that the fixed air was formally preſent in the fermenting maſs, or that it afforded all the materials to form it; now let us ſuppoſe that the quantity of heat in the two airs before combination, was in each as *ten*, or in other words, that they were capable of containing that quantity in a latent ſtate, eſſential to their exiſtence as matter in that form: when they unite, they form a very different kind of air, which is not capable of combining with ſo much heat, and perhaps quite foreign to its exiſtence as that kind of matter; we will ſuppoſe then that it can combine with but a quantity of that heat *as five*, the conſequence then muſt be that there is a quantity of redundant heat as *fifteen*, and there being no bodies at hand undergoing any changes in their properties, by which their capacities to unite with heat as a principle, is increaſed, it becomes *mechanically diffuſed* among thoſe bodies which are neareſt to it, it gives the redundant heat to the feeling hand, to the atmoſphere, to the thermometer and to the fermenting fluid, by that law of *ſenſible* heat which proves that it is equally diffuſed thro' all bodies; and as the *cauſe* of heat continues to act, ſo the effect muſt continue to enſue until the fermentation is compleated. With the eſcape of the elaſtic fluid there is an hiſſing noiſe, and of conſequence an *inteſtine motion*; theſe phe-

nomena have had more attention paid to them than they deſerve, and they have been ſuppoſed to be the moſt infallible ſigns that this proceſs is going on; theſe we know are called the working of liquors, but they are very fallacious, and have been the ſource of much error, as I apprehend, and I believe, that even the great Sir John Pringle, truſting to ſuch appearances, has ſuppoſed that putrifaction had taken place in experiments, where there really was no putrifaction, but I am ſtill more firm in the belief, that he was in ſome inſtances wrong in attempting to determine the *degree* of putrifaction from the degree of theſe appearances; we ſhall illuſtrate theſe remarks in the fourth ſection. *An alteration of the ſenſible qualities* of the fermented body is a more certain and univerſal circumſtance than any other, therefore I think I am ſafe in aſſerting that we can have no certainty of fermentation having taken place in any caſe without it, for when an animal ſubſtance putrifies it is changed from an inodorous body to one that is very rank and fetid, and ſugar when fermented, is capable of yielding a highly intoxicating ſpirit, and if fermented longer becomes highly acid, as we know from the formation of vinegar, which we ſuppoſe is owing to the loſs of its phlogiſton.

SECTION III.

Products of Fermentation.

AFTER all the phenomena above mentioned have continued for ſome time, which is longer or ſhorter, according as the exciting cauſes

of the proceſs have been more or leſs applied, the fermentation becomes for a while ſtationary, and the vegetable fluid gets different names according to the nature of the vegetable itſelf: the fermented juices of grapes are called *wines*, and the juices of almoſt all fruits which are ſweet when ripe, are capable of affording *analogous* liquors when fermented, ſuch as the juices of *currants*, *apples*, *peaches*, *pears*, &c. certain grains may alſo be fermented by ſimilar proceſſes, as *barley*, *wheat*, *rye*, and ſome others: all theſe when firſt fermented, and then diſtilled, yield *ardent* ſpirit, which by repeated diſtillations will afford alcohol. Brandy is the ardent ſpirit obtained by diſtilling the fermented juice of the grape, whilſt *rum* or *ſpirit*, are the liquors diſtilled from molaſſes and water; beer is the fermented extract of barley, to which is added a decoction of hops, which as a bitter is an antizymic, and prevents it from haſtening on to the acid ſtage of fermentation.

There is a conſiderable variety in wines which does not depend ſo much upon any difference in them as fermented liquors, but in moſt caſes, upon ſome addition not eſſential to them as wines, for inſtance, ſome have a peculiar flavour which cannot be analized, and may be but in very ſmall quantities in them, for who can analize the flavour of the peach? others differ only in being weaker, that is, in having a larger quantity of water, others again have the aſtringent acid combined with them, hence are called *rough wines*; ſome from being weak ſoon become ſour, before a due degree of fermentation has taken place in the whole maſs, and as for the dif-

ference in colour, it is ſometimes owing to cauſes which neither influence the qualities of the wine, nor the fermentation it underwent, but the moſt material difference in the qualities of *rich* wines, ſuch I mean as have a proper quantity of water, is their *age*; this excellence ſeems eſpecially to be owing to the more perfect fermentation and aſſimilation of the different parts of the wine, for then the unfermented ſaccharine part becomes perfectly vinous, whilſt the vinous part already generated is ſo ſtrongly antizymic as not to ſuffer any part to become acid.

Wines ſomewhat diluted and expoſed to the neceſſary conditions of fermentation go on to the ſecond ſtage which is called the acetous or acid fermentation, and the chief difference between this and the vinous is, that all the phenomena are in a leſs degree: the reſult of this fermentation is *vinegar*; the explanation of ſome of the varieties of vinegar, may be underſtood from what we have ſaid above.

SECTION IV.

Diſtinction between a mere Eſcape of Air, and a True Fermentation.

FERMENTATION is ſuppoſed to take place in another proceſs, I mean in making bread, but I think we ought to be very cautious in admitting that a true fermentation takes place, or is even neceſſary in its preparation: I ſhall perhaps in the courſe of this ſection, uſe the common language, but when the word *fermentation* is applied to the making of bread, I wiſh it would be

underſtood to expreſs nothing more than the effect produced on flour by yeaſt or leaven.

Of the origin of fermented bread we have no certain account; I cannot however omit relating the very elegant conjecture reſpecting it given us by our *late* chemical profeſſor. He ſuppoſes that ſome careful houſewife had mixed the unbaked ſcraps of a former mixture with ſome freſh dough, and he imagines her ſurpriſe at finding the bread improved by this proceſs of economy; what gives greater plauſibility to the conjecture is, that it is certain that leaven was the firſt ferment uſed for *raiſing* bread; but ſince later experiments have taught us that ſeveral ſubſtances in the act of fermentation will raiſe bread, leaven has gone out of uſe, and *yeaſt*, where it can be had, has almoſt univerſally ſupplied its place. The common idea of a ferment is, that it is capable of *aſſimilating* ſubſtances to its own nature: this is cutting the knot, for we ſee no reaſon why particular ſubſtances ſhould have ſuch power whilſt others have not, and in fact it explains nothing. In many ſuppoſed caſes of aſſimilation, we ſee ſources of falacy and error, in others we muſt ſtill aſſent to the common opinion. In the making of bread, we deny the idea of any ſuch aſſimilation, or even of any true fermentation; * but let us attend to

* This opinion, ſupported by experiments, was communicated to ſeveral gentlemen, and eſpecially to Doctor Rush, ſo early as January 1789. When I ſubmitted this diſſertation to the Doctor for his approbation as a profeſſor of the college, he was pleaſed to interline a compliment upon this diſcovery. He did me the honor to declare, that he "readily adopted it, "and afterwards publicly taught it, with acknowledgements to the author, "in his *Lectures on the application of Philoſophy, Chemiſtry, Medicine and Econo-* "*my to domeſtic and culinary purpoſes.*"

I have made no acknowledgments for the idea to any body, but claim it as original, although the ſame ſentiments were *afterwards* publiſhed in this

the proceſs itſelf, and the phenomena attending it. A quantity of flour is mixed with a certain proportion of yeaſt and water, and made of the conſiſtence of dough; it is then baked in a manner too ſimple to be deſcribed, and *in one hour* from the beginning to the end of the proceſs, the bread is made, and is perfectly good. We are juſtly ſurpriſed at the ſhort time required to *ferment* the bread, eſpecially when we conſider that ſugar and water, the moſt fermentable mixture known, requires twenty four hours before fermentation proceeds to any great degree in it; this reflection firſt ſuggeſted the idea that the fermentation of bread is not analogous to the fermentation of ſugar and water, in conſequence of which the following experiments were made in December, 1788, in the preſence of my fellow candidate A. J. De Roſſet, and two other gentlemen at that time ſtudents of medicine.

Experiment Firſt.

Part of a quantity of dough which had been raiſed in three quarters of an hour, was put into a retort, and the proceſs of diſtillation performed upon it; ſome liquid came over into the recipient, which was not inflamable, and as taſteleſs as pure water. It is allowed by all chemiſts that *vegetables*, in the firſt ſtage of fermentation, yield a vinous ſpirit in diſtillation; here then we muſt conclude, either that the *dough* had not fermented, or that fermented wheat flour will not yield a vinous ſpirit, but the practice of this country

city. The diſcovery may perhaps be but of little importance, I have however, inſerted this note to obviate any charges of plagiariſm that might be offered againſt me.

proves that wheat *will ferment*, and yield a *vinous ſpirit*, when diſtilled, therefore I conclude that the dough had not fermented.

Experiment Second.

The other parcel of the ſame dough was baked, and yielded a perfectly fermented bread.

Experiment Third.

The ſame dough remaining in the retort uſed in *Exp.* 1. was rendered more fluid by the addition of a little water, and kept in a warm room: in nine hours there were no appearances of fermentation; in ſixteen hours an eſcape of air, a hiſſing noiſe, &c. ſeemed to indicate that the proceſs had proceeded ſome time: it was now diſtilled again, and yielded a little acid fluid, and a ſmall quantity of a weak *vinous ſpirit*.

Does it not ſeem true therefore, from theſe experiments, that flour requires even more than nine hours before it ferments, and if bread can be made in *one* hour, it amounts almoſt to a demonſtration, that the fermentation of bread is not analogous to the vinous fermentation, or even the fermentation of flour.

From a variety of facts, I am induced to give the following explanation of the proceſs: Yeaſt is a fluid containing a large quantity of fixed air, or aerial acid, and the proportion is greater in proportion as the fluid is colder: As ſoon as the yeaſt is mixed with the dough, heat is applied; this extricates the air in an elaſtic ſtate, and as it is now diffuſed through every particle of dough,

every particle muſt be raiſed; the viſcidity of the maſs retains it: It is now baked, and a ſtill greater quantity of air is extricated by the increaſed heat, and as the cruſt forms, the air is prevented from eſcaping; the water is diſſipated; the loaf is rendered ſomewhat dry and ſolid, and between every particle of bread we find a particle of air, as appears from the ſpongy appearance of the bread, owing to the apparent vacancies which the air had made, by inſinuating itſelf into it.

But let us attend to another fact, which thoſe who ſupport the doctrine of fermentation will find a great difficulty in explaining: If the dough be kept longer than the proper time, without baking, it falls again as it is termed, or as I would expreſs it, all the fixed air which raiſed it is diſſipated, and then being baked we get heavy bread, exactly like the bread made with flour and water, and haſtily baked, which we know is taſteleſs. Some will perhaps ſay the fermentation is over, but this cannot be admitted; for after the *vinous* comes the *acetous* fermentation, but in this inſtance we have no ſigns of acidity, neither can we ſuppoſe that any ſubſtance is ſo fermentable as to finiſh the vinous ſtage of fermentation in nine hours, for we found that the ſame materials in more favourable circumſtances, required ſixteen hours before the proceſs *began*; ſometimes, however, we do find heavy bread that is acid, but in ſuch caſes I conclude that the acid came from the yeſt, which had proceeded to that ſtage.

Another fact I would wiſh to be attended to is, that fermentation alters the eſſential properties of bodies, as we have ſhewn in Sect. 2d. and 3d.

but bread is not chemically nor eſſentially different from flour, for we can actually ſeparate the different conſtituent principles of flour from bread; beſides, bread itſelf infuſed in water, and expoſed to the neceſſary cauſes of fermentation, will actually ferment, and no doubt yield a vinous ſpirit in diſtillation.

If we might be allowed to reaſon from Sir Iſaac Newton's axiom, " that no more cauſes of natu- " ral phenomena are to be admitted than are ſuf- " ficient to explain them," we can produce three facts that will prove clearly, that fermentation is *not neceſſary* to make bread ; from which I infer, that it does not take place. The bakers in this city find much difficulty in getting good yeaſt in ſummer, for fermentation goes on ſo rapidly in the warm weather, that it grows ſour in a ſhort time; they can however, make it anſwer their purpoſe. They diſſolve a ſmall quantity of pot-aſh in as much water as is neceſſary to make their bread ; this they mix with their yeaſt and flour : in leſs than ten minutes their bread is fit to bake, and has every property of what is called the beſt fermented bread. We need ſcarcely explain this fact; every perſon moderately acquainted with the ſubject, knows that pot-aſh is an alkali united to much fixed air, and we think the acid in the yeaſt ſets it at liberty, which is the cauſe of the raiſing of the bread, as before explained.

A ſecond fact that I ſhall mention, was given us by our late chemical profeſſor Doctor Ruſh, in the courſe of lectures which he delivered in the winter of 1788-9,, he informs us, that near Saratoga, there are two mineral ſprings, the wa-

ters of which have all the properties of the famous Pyrmont water, in other words they are highly impregnated with fixed air. This water when mixed with flour into dough, is ſufficient without yeaſt, to make a very light and palatable bread.

A third fact appears deciſive; we know that a little ſalt is added to the bread by our bakers; this ſuggeſted the idea of ſupplying it in the following manner, which I confeſs is rather fanciful: I procured ſome nice chryſtals of the ſalt formed by the foſſil alkali and fixed air and diſſolved them in water ſufficient to make a ſmall loaf of bread, to this I added a little of the *marine acid* commonly called ſpirit of ſea-ſalt; fixed air was generated, but was abſorbed by the cold water; it was then mixed with flour, ſet in a warm place to riſe and ſhortly after baked; and I had the exquiſite pleaſure to obtain a tolerably light loaf of bread, ſuch as any one would have ſuppoſed to have been fermented, which was ſeaſoned by the ſea-ſalt, formed by the union of the foſſil and the ſpirit of ſea-ſalt; whilſt the fixed air of the foſſil alkali was diſengaged in order to raiſe it.

SECTION V.

Zymics and Antizymics.

THIS is by far the moſt difficult part of the ſubject; that many ſubſtances have the power of exciting fermentation and others of retarding it, cannot be denied; but I am far from believing that chemiſts are quite correct upon this ſubject; whilſt the one phenomenon, *the eſcape of air*, is ſo much attended to as the diſtinguiſhing character of fermentation, we can ne-

ver be accurate ; thus I ſuſpect that when a ſmall quantity of an alkaline ſalt is ſaid to be an antizimic with reſpect to *milk* it abſorbs the *acid* that is generated in the fermentation, ſo that it cannot be taſted, and hence preſerves the milk ſweet ; *chalk* on the other hand is ſaid to be zymic and to accelerate the vinous fermentation; but is it not probable that in ſuch caſes a ſmall quantity of acid is generated in the vinous liquor, which unites to the chalk, ſets the fixed air at liberty and it then eſcapes by mere effervescence ?

Subſtances that have fermented, yield a matter that is ſuppoſed to poſſeſs the properties of exciting fermentation in other bodies ; for inſtance *yeaſt*, and ſuch ſubſtances are ſaid to poſſeſs a power of *aſſimilation* ; but we cannot account for the operation of the yeaſt in theſe caſes, for we by no means know why they tend to diſſipate the phlogiſton of ſuch ſubſtances, neither do we ſee any ſimilarity in the chemical compoſition of different zymics and antizymics ; that yeaſt excites the vinous fermentation in liquors I muſt not deny. I cannot however omit relating a ſolitary experiment ; I took a quantity of ſugar and water, and divided it into two equal parts, I put them into two veſſels of the ſame ſize and ſhape, and expoſed them to the ſame temperature of heat ; to one I added yeaſt, to the other none ; after ſome time they had both become conſiderably acid ; they were then both ſaturated with an alkali, and the quantity required for that purpoſe was almoſt exactly alike in each. Here then it would ſeem that the yeaſt was entirely paſſive. I can make no remarks upon this experiment ; I leave it to be confirmed or rejected as future facts ſhall dictate. Mr. Henry of Mancheſter, in a

very elegant memoir, preſented to their Philoſophical and Literary Society, on the ſubject of fermentation, aſſerts that "It is a well known fact to the brewers of malt liquor, that *wort* cannot be brought into the vinous fermentation, without the addition of a ferment." But when we conſider the analogy between beer and other vinous fluids, and that all *wines*, *cyder*, *perry*, &c. ferment without any addition: I think we have great reaſon to doubt the fact. But I cannot *as yet* diſprove his idea by experiment.

In the memoir above mentioned, the author ſeems to think that *fixed air* is the true cauſe of fermentation in vinous liquors, and he tells us of the excellent taſte afforded to *punch* by being impregnated with it. Fixed air it is well known improves the *taſte* of liquors, but we cannot ſuſpect that it made the punch ferment in his experiment; but he tells us that he made an *artificial yeaſt* by impregnating flour and water with fixed air, that with this yeaſt he made *beer* (perhaps he might have made it without it) and vinegar, and that he *fermented* bread with it: as for its fermenting bread, we might readily allow that it would raiſe bread upon the principles already laid down in Section 4. and when he tells us how quick the fermentation takes place in his liquors, when expoſed to a gentle heat, may we not juſtly ſuppoſe that the warmth extricated the fixed air, that he had artificially combined with it, and that from this phenomenon alone he had ſuppoſed fermentation to be going on in them? Fixed air as we have already ſaid, is the cauſe of the briſkneſs, pungent taſte and ſparkling appearance of vinous liquors; and it is remarkable that *in equal circumſtances* the colder they are the more air they contain: I have been told as an argument againſt

me in ſuppoſing that bread does not ferment becauſe it is *raiſed* ſo quickly; that a barrel of beer may be kept in a vault in the ſummer, without fermenting, but if it is hoiſted up into the air it will ferment in two or three hours. But may I not juſtly concludd that this *apparent* fermentation was only owing to the eſcape of fixed air? but ſay ſome there is alſo a change of properties; the beer becomes flat and; vapid but this is the natural conſequence of looſing its fixed air which is the cauſe of its briſkneſs. It is alſo a curious fact that the fixed air in liquors muſt be in a peculiar ſtate, otherwiſe they do not poſſeſs that briſkneſs or pungency we ſpoke of: in fact it muſt be on the point of aſſuming its elaſtic form: hence liquors are not ſo briſk in cold as in warm weather, and a connoiſſeur in *porter* for inſtance will tell you, that a bottle ſhall open very briſk in a warm day, and upon the coming on of cold weather, all the reſt ſhall be flat and dead; but let them be corked up, and kept in a warm room for a few days they will all recover their briſkneſs, nay, I have ſeen a bottled opened in a cold day that has been quite vapid, which was made briſk and lively by corking it up tight again, and ſetting it for ten or twelve minutes in a baſon of water little more than milk-warm.

SECTION VI.

Some analyſis of Animal Matter, the difference between Animal and Vegetable Fermentation.

WHEN we conſider that almoſt, and perhaps all animals are ultimately derived from vegetables, we muſt be very much ſurpriſed at the difference that ſubſiſts between the objects of the two kingdoms. They ſhew their difference ſur-

prizingly in the ſpontaneous changes which they undergo, when expoſed to the neceſſary conditions of fermentation, for animal ſubſtances emit a fœtid diſagreeable ſmell, and the elaſtic fluids is the vapor of *volatile alkali*.

If with Doctor Cullen we may believe that only certain parts of vegetables are alimentary, we might ſuppoſe that the parts of the animal formed of thoſe alimentary parts, would in ſome meaſure retain their nature;* his idea is, that it is only the *acid*, *ſugar* and *oil* of vegetables that render them nutritious, and if that idea were juſt, we ought to find them in thoſe animal fluids that are immediately formed of the food; that an acid is preſent in the *blood*, at leaſt neutralized by ſome ſaline baſe, is eaſily demonſtrated, but it may be doubted whether it is uſeful to the animal; and we have irrefragible proofs that an *oil*, or at leaſt the conſtituent principles of an oil exiſt in the blood, for we obtain it by diſtillation; the taſte of the urine of *diabetic* patients, proves the preſence of ſugar in the ſyſtem, which may have either exiſted formally in the blood, or been formed by ſecretion, and the principles of it at leaſt muſt have been afforded by the vegetable food. I know of no direct experiments to aſcertain the preſence of ſugar in the blood; I am in poſſeſſion of one, however, that would ſeem to give plauſibility to that idea. As Mr. Bergman had obtained the *acid of ſugar* from gum arabic, and from thence

* Since the five laſt ſections were printed off, I have met with a fact, that tends to throw much light on this ſubject, and proves that *animal* and *vegetable* matters are more allied to each other, than chemiſts have heretofore imagined; in vol. iv. part 2. of the laſt edition of the Encyclopedia Britannica, under the article CHINA, §. 114, we find the following obſervation. "Another kind of wine is uſed by the Chineſe or rather Tartars, called *lamb-wine*. It is *very ſtrong*, and has a diſagreeable ſmell; and the ſame may be believed of a kind of *ſpirit diſtilled from the fleſh of ſheep*."

concluded that it contained *ſugar*; I was ſtruck with the analogy between *gum arabic* and the *coagulable lymph* of the blood; I treated this laſt mentioned ſubſtance according to the manner for obtaining *acid of ſugar* from ſugar, gum arabic, &c. that is by boiling it with ſtrong nitrous acid; the mixture when cold yielded ſome ſmall chryſtals, which precipitated lime from a ſolution in lime water in the ſame manner as the acid of ſugar does. It is true, the blood has not a ſaccharine taſte, neither has gum arabic, and perhaps ſome trifling circumſtances, as an intimate chemical union of ſugar with an oil, may deſtroy all the ſenſible qualities of the ſugar, yet as gum arabic yields nearly the ſame reſult in chemical proceſſes that ſugar does, it would be wrong to aſſert that it contains no ſugar; nay, barley has no ſaccharine or ſweet taſte, yet the trifling circumſtance of *malting* will make it remarkably ſweet, and confeſſedly ſaccharine; and who wonld ſay that barley did not contain ſugar, before it was malted, merely becauſe it could not be taſted?

There have been, however, ſo few experiments made to determine the cauſes of the difference of animal and vegetable fermentation, and the ſubject is in itſelf ſo truly difficult, that I muſt candidly confeſs it is far beyond my reach.

FINIS.