bilitari truncum aortæ, et ad aneuryſmata reddi pronum. Demonſtrat etiam, in ipſo ſanguine ubique terram veram calculoſam circumvehi, nec in renalibus ſolum viis deponi, ſed ibi hærere et congeri, ubi ruptæ ſunt leviſſimæ membranæ vaſorum, et attractio terrearum molecularum ad aſperas inæquales ſuperficies major eſt.

XVI. *A Memoir on the* Lacrymæ Batavicæ, *or Glaſs-Drops, the* tempering *of* Steel, *and* Effervescence, *accounted for by the ſame Principle. By* Claud, Nic. le Cat, *M. D. F. R. S.* &c. *Tranſlated from the* French, *by* T. S. *M. D.*

Read June 15. 1749. THE Glaſs-Tear, or Drop, commonly called *Lacryma Batavica*, or *Lacryma Boruſſica*, becauſe it was firſt made in theſe Countries, is much celebrated among Natural Philoſophers, upon account of the ſingular Phœnomena which it exhibits, and which have for a long Time exerciſed their Sagacity.

The Make of this Drop is as ſimple as its Explanation is difficult. It is the Work of the meaneſt Workman in a Glaſs-houſe. On the Top of an iron Rod they take up a ſmall Quantity of the Matter of Glaſs in Fuſion: They let it drop into a Pail of Water: The Drop makes that Part of the Water which it touches, to boil with a hiſſing Noiſe, as a red-hot Iron would do, which it reſembles in that Inſtant; and when it does not break in this Operation,

ration, as it moſt frequently does, it forms the little pyramidal Maſs, which is known by the Name of a Glaſs-Drop; the Effects whereof I will firſt relate, and then endeavour to account for them.

Experiment 1. This Drop is of ſuch Hardneſs and Reſiſtance, that it bears ſmart Blows of a Hammer, without breaking.

Exper. 2. Nevertheleſs, if you grind the Surface of this Drop which reſiſted the Hammer, or if you only break the Tip of the ſmall End or Tail, the Whole ſhatters into Powder.

Exper. 3. This Shattering of the Drops is attended with a loud Report; and the Duſt or Powder to which it is reduced, ſhoots out, and ſcatters all around.

Exper. 4. If the Drop be ground with Powder of Emery, imbibed with Oil, it often eſcapes breaking.

Exper. 5. If this Experiment be made in the Air-Pump, the Drop burſts with greater Impetuoſity, ſo as ſometimes to break the Receiver: and its Duſt is finer than when done in the open Air; and if it be made in the dark, the Drop in burſting produces a little Light.

Exper. 6. If this Drop be annealed in the Fire, it loſes all theſe Singularities; and being reduced to the State of common Glaſs, it eaſily breaks under

der the Hammer; and does not burſt upon breaking the ſmall End.

Exper. 7. The Drops that are made by letting them cool in the Air, produce no other Effects than thoſe which have been annealed.

The firſt natural Philoſophers who endeavoured to inveſtigate the Cauſe of theſe Phænomena, imagined that they found it in the Air. Some of them ſuppoſed, that this Air was ſhut up in the Drop by the Cruſt which the cold Water forms on its Surface while it is yet red-hot; and attributed its Rupture to the Violence with which this Air iſſued thro' the too narrow Paſſage made for it, in breaking the ſmall End of the Drop. Others maintained on the contrary, that the Drop, in this State, contained no Air at all, nor any thing but Particles of Fire, or ſubtile Matter; or, in one Word, a Vacuum of Air; and that the ſudden burſting of the Drop was occaſioned by the impetuous Entry of the Air into this ſort of Vacuum. In fine, the *Carteſians* have ſubſtituted their ſubtile Matter in the room of this exterior Air, and ſay, that the Drop is burſted by the leſs ſubtile Particles of this Matter; which entering with Force into the Drop by the Opening made therein, and finding large Pores on the Inſide, and ſmall ones on the Outſide, burſt the Sides of the Drop, by ruſhing from the Centre to the Circumference, wherewith its Paſſage is obſtructed.

Meſſ. *Mariotte* and *Homberg* came afterwards; Being provided with an Air Pump, they cauſed one of theſe Drops to be broken *in Vacuo*; and *Hom-*

berg having obſerved, that it broke therein better and with a louder Report than in the open Air; they both inferred, that neither the impetuous Entry of the outward Air, nor that of a Fluid ſomewhat leſs groſs, could be the Cauſe of this Shock; becauſe the Receiver of the Air-Pump is void of theſe Fluids; and even if a little ſhould remain therein, it is too much rarefied, and too thin to be capable of ſuch an Effect.

Mr. *Mariotte*, thro' ſome Remains of Attachment to an Opinion, which he had held to that Time, did not intirely exclude the exterior Air from the Cauſe of the Phænomenon of the Drop; but thought proper to add another to it; which he makes uſe of as a Subſtitute in Caſes like thoſe of the preceeding Experiment, where the Inſufficiency of the Air, or of a Fluid nearly ſimilar to it, plainly appears.

Mr. *Homberg* ſhews no Indulgence to the exterior Fluid; and aſcribes the Whole to the new Cauſe, which is, the Quality of temper'd Glaſs, which the Drop acquires, like Steel, by being thrown red-hot into cold Water. This Tempering, according to theſe great Academicians, confers at the ſame time more Springineſs to the Parts, and leſs Connection with each other. When a Steel Sword-Blade is bent forcibly, it breaks more eaſily than one of Iron; and the Jarring which is occaſioned by its Spring, is capable of breaking the other Parts of the Blade: And thus we ſee, that it generally breaks into ſeveral Pieces. This Blade is the Image of the *Lacryma Batavica*, or Glaſs-Drop.

This is the Point to which I found Things brought, when I began to ſtudy the Phœnomena of the Glaſs-Drop. The

The Air was partly baniſhed from the Inſide of this Maſs of Glaſs: There is none in the liquid red-hot Matter of a Glaſs Furnace. It was purely out of Complaiſance for a generally received Opinion, that Mr. *Mariotte* allowed the exterior Fluid any Share in the Phænomenon; and Mr. *Homberg* put the finiſhing hand to its Excluſion. But the Sort of Temper given to the Drop by plunging it red-hot into cold Water, and its Compariſon with temper'd Steel, is not ſo much a Cauſe as a Compariſon: And moreover, is this Compariſon very juſt? Can there be any between a long, thin Sword-Blade, which breaks into two or three Pieces, and a thick inflexible Maſs of Glaſs, which flies into Powder. The Tail alone of the Drop might ſeem to favour this Parallel: But an Experiment, which I made, entirely deſtroys this Opinion, and proves, that it is not the Spring, or the Vibrations of the Parts of the Drop, that occaſion its burſting.

I put about half the Tail of a Glaſs Drop into a Vice between two Bits of Deal-board of about a Finger's Breadth. I ſcrew'd the Vice, till I ſaw this ſmall Cylinder or Thread of Glaſs make Impreſſions in the Wood on each Side for its Lodgment, in order to be ſure that it could not be ſuſceptible of Vibrations. In this Condition I broke the End of the Tail, ſupporting it on my Nail, to prevent forceing any Part but the End which I intended to break; and in order to be the more certain of giving no Shock to the Part that was ſqueezed in the Vice. My Drop flew into Powder as uſual; and the Portion ſecured between the two Bits of Wood, perfectly retained its Figure in the Impreſſions wherein

it was lodged. But when I touch'd this little Cylinder, it was reduced to Powder, much in the ſame manner as is ſaid to have happen'd to ſome Men who had been ſtruck with Lightning. Now, it was not poſſible for this Glaſs to receive, or convey to the Body of the Drop any Vibrations; or if any, they muſt be infinitely ſmall; and yet the Effect was preciſely the ſame as uſual. Therefore the Syſtem of Vibrations is not happier than thoſe invented before it.

It is among the Glaſs-workers, and in their Art, that the Secret of the *Lacryma Batavica*, or Glaſs-Drop, is to be ſought; and there it is that I think I have diſcover'd it.

All thoſe who have ſeen Glaſs-houſes know, that when a Piece fails in the Hands of a Workman, he throws it aſide; and this Piece is not long expoſed to the Air, before it breaks in Pieces: And when the ſame Workman has ſucceeded in making a Piece, and is willing to preſerve it, he takes great Care not to let it cool in the Air; but carries it hot into another Oven of a moderate Heat, where he leaves it for a certain Space of Time. And this laſt Operation is called *Annealing the Glaſs.*

A natural Philoſopher, who is Witneſs to this Management, ought to inquire into the Reaſons and Neceſſity of it.

How comes it that the Glaſs, which cools in the Air, breaks; and when it has been nealed, it does not break? This is the Reaſon, if I am not miſtaken.

A Bit of melted Glaſs, red-hot and liquid at the ſame time, is in that State, purely becauſe its Particles are divided by ſo great a Quantity of Particles

of

of Fire, or ſubtil Matter ſo violently agitated, that theſe component Parts of the Glaſs do hardly touch one another: They ſwim, if I may be allowed the Expreſſion, in a Flood of this Matter of Fire; and for this Reaſon it is, that melted Glaſs affects the Colours of Flame.

When this Subſtance is expoſed to the Air, the Coolneſs of this Fluid, which touches the Surface of the Glaſs, cools that Surface firſt; that is, brings the Particles nearer together, braces their Pores, and thus impriſons the Particles of Fire, which ſtill fill the Inſide of this Subſtance. While theſe fiery Particles find Pores enough on the Surface, to move freely, the Glaſs continues whole; but when the Glaſs grows colder, that is, when the Pores of its Surface begin to confine theſe fiery Particles; then their whole Action is exerted againſt the Parts of the Glaſs, which they break into a thouſand Pieces. In order to avoid this *Fracas*, nothing more is requiſite than to keep the Pores on the Surface of the Glaſs wide enough, that the fiery Particles contain'd therein may paſs through, and fly off inſenſibly. Now, this is what is done, by putting the hot Piece of Glaſs into an Oven, the moderate Heat of which keeps theſe Pores open to a certain Pitch, and yet allows the Glaſs to acquire its due Conſiſtence in this State of middling Poroſity: Wherein conſiſts the Annealing of Glaſs and other fuſed Subſtances.

Hence it appears, that all unnealed Glaſs carries within itſelf its Principle of Deſtruction, which is the Matter of Fire impriſoned. But the *Lachryma Batavica*, or Glaſs-Drop is in this reſpect, in a worſe Caſe ſtill than unnealed Glaſs: For beſides that it has not been expoſed to this ſecondary Heat, which

which keeps its Pores open, till the Glaſs has acquired its due Conſiſtence, for Fear that the Coolneſs of the Air alone ſhould not cloſe its Pores ſoon enough, and impriſon a ſufficient Quantity of the igneous Matter, it is ſuddenly thrown into cold Water, which by its Coldneſs and Weight is fitter than the Air to produce ſuch an Effect ſpeedily and effectually. Wherefore the only ſurpriſing Circumſtance in theſe Glaſs-Drops is, that any of them remain without breaking, by the great Quantity of igneous Matter ſuddenly ſhut up in them by the cold Water. And indeed this Accident befalls more than one half of them; and thoſe that eſcape, doubtleſs owe their Preſervation to the ſpherical or cylindrical Figure of the compact Shell, which the Coldneſs of the Water forms on their Surface: For it is well known that this Figure produces an Equality of Reſiſtance on all Sides, which conſiderably encreaſes the reſiſting Force: And this is the firſt Reaſon why, as ſoon as this Æquilibrium is broken, either by rubbing away one Side of this Surface, or by making a Hole in it, or, in fine, by breaking the ſmall End of the Drop; the Reſiſtance is inſtantly overcome, and the igneous Matter, impriſoned within the Glaſs, and conſtantly upon the Strain againſt it, burſts it into Powder.

This deſtroyed Æquilibrium is but one Diſpoſition that favours the Effect of the impriſon'd igneous Matter: But the Communication which is opened for it with the ſubtile exterior Fluids, rouſes this Matter which is in a State of Inactivity, develops its Spring, kindles it ſomewhat in the Manner of the Phoſphorus, which produces no Effect while cloſe

ſhut

ſhut up, but takes Fire, as ſoon as a free Communication with the outward Air is given it.

On the Union of theſe Cauſes depend the Phœnomena of the Glaſs-Drop. It is of a Hardneſs that reſiſts the Strokes of a Hammer, becauſe the violent Condenſation, given to its Surface by the cold Water, into which it was thrown when in a ſoft State, render'd its Texture very cloſe, compact, and conſequently hard.

It burſts with great Noiſe; and in ſo doing it retains the Character of all the Effects produced by the Exploſion of the igneous Matter.

Its Duſt flies two or three Feet all around, becauſe it is puſh'd forward by the Action of a Fluid contained in its Centre; which would not happen, if it had been the Effect of an exterior Fluid. This ſame Duſt of the Glaſs-Drop darts forward with greater Force in the Air-Pump than in the Air, becauſe the Air is an Obſtacle, of which it is freed in the Receiver of the Air-Pump: Wherefore it ſometimes breaks the Receiver; and for the ſame Reaſon its Duſt is finer, that is, more minutely broken, as being done by a ſtronger Power, and leſs counterbalanced.

This violent Exploſion produces Light, becauſe the Property of ſhining Lightning is always the Effect of ſuch an Exploſion of the Matter of Fire: Wherefore this Fact affords another Proof, that this Matter is the Principle of the Phœnomenon of the Drop.

If the Surface of the Drop be ground with fine Powder of Emery, imbibed with Oil, it frequently happens, that it does not burſt; becauſe the Sort of oily Maſtic that reſults from this Mixture, ſtops the Pores

Pores of the Drop, and prevents the ſudden Communication of the exterior Fluids with the impriſoned igneous Matter; and as Glaſs cannot be ground with very fine Emery and Oil, but by long rubbing; ſuch rubbing heats the Drop, and gradually opens the Pores ſo as to grant an inſenſible Paſſage to the igneous Matter, whereby the Drop becomes at laſt in the ſame Caſe with nealed Glaſs; and in the Caſe in which itſelf is, when it is put into the Oven to be nealed.

When a Glaſs-Drop is made, by ſuſpending it in the Air only, it does not break ſooner than nealed Glaſs: Becauſe as this ſmall Maſs of Glaſs retains its Heat a long while in the Air, the Heat ſerves as a Nealing-Oven, and keeps its Pores dilated long enough for the igneous Particles to find a free Paſſage.

The Principles, by which I have accounted for the Effects of the Glaſs-Drop, are not confined to this Phænomenon alone: They are more general than is commonly imagined. Some Corollaries, which I ſhall deduce from them, will prove what I advance.

The Tempering of Steel.

Steel, like the Glaſs-Drop, acquires its Hardneſs by being plunged into Water: And if Meſſ. *Mariotte* and *Homberg* had compared them together in this Circumſtance alone, they had been in the right.

The moſt celebrated natural Philoſophers, in order to account for the tempering of Steel, have had recourſe to different Arrangements of its Parts produced by the Fire, and fixed, by the Cold of the Water, in the new State, in which the violent Heat had put them.

The

The Mechaniſm of the tempering of Glaſs Drops, applied to that of Steel, is the the moſt ſimple of all the Hypotheſes, and anſwers all its Properties, which are theſe:

1. Tempered Steel has a coarſer Grain. 2. Is is increaſed in Bulk. 3. It is harder and brittler. 4. By annealing it becomes leſs brittle.

Explanation. Steel made red-hot is filled and ſwelled, and its Pores dilated, by the igneous Matter. In this State, the cold Water, into which it is thrown, compreſſes and cloſes the Parts of the Surface, while the impriſoned igneous Matter dilates the Pores within: Thus the Texture of Steel becomes more compact by theſe two Cauſes, while its Pores are dilated.

Theſe large Pores conſtitute the coarſe Grain of tempered Steel. Its Dilatation by the igneous Matter, which could not be thoroughly condenſed by the Cold of the Water, cauſes its augmented Bulk: The cloſe Texture of the Subſtance that ſurrounds the Pores, and the impriſoned igneous Matter, occaſion its Hardneſs and Brittleneſs. Its Recoction or Annealing deprives it of this Brittleneſs, and of a Part of its Hardneſs: Becauſe it opens this Texture, which it relaxes at the Expence of the neighbouring Pores, and drives the igneous Matter out of it.

Fermentation.

The Fermentation of Acids and Alkali's ſeem to me to be another Corollary of the ſame Principle.

Firſt, It is pretty univerſally allowed, that the acid Particles have the Figure of ſmall Needles; and that Alkali's are ſpheroidal or polyhedrous Bodies with a vaſt Number of Bodies proper to admit the acid Needles.

Secondly, Experience ſhews, that Salts are alkaliſed by Fire, and that our Juices are alkaliſed by Heat, *&c.* What can the repeated Action of the Fire produce on Salts, in order to alkaliſe them? It calcines them, blunts their Points, and hollows them with a vaſt Number of Pores; and we ſee with the naked Eye, that Calcination has this Effect on all Bodies. In a word, it converts an angular very ſolid Body into a very porous and light Spheroid; and this Body is an Alkali by the firſt Suppoſition.

Thirdly, Calcination introduces, and generally leaves in the Pores of the calcined Body, after the Operation, a great Quantity of igneous Matter. This Matter is perceptible to the Senſes in the *Lapis Bononienſis*, which becomes a Phoſphorus by Calcination; in Lime-Stone, which by Calcination is furniſhed with ſo great a Quantity of igneous Matter, that in the Effervescence, which is raiſed in it by throwing a little Water on this Stone, you may kindle Sulphur or a Match by it. The Alcaline, or alcalized Salts alſo, that is, thoſe which are calcined, have their Pores full of the igneous Matter.

Fourthly, Such is the Nature of the igneous Matter, that it tears aſunder whatever oppoſes its Paſſage,

ſage, and makes it fly off with a Report. This Principle is univerſally allowed: The Effects of Gunpowder, of Volcano's and Earthquakes, prove it: And to come nearer our Subject, unnealed Glaſs breaks in the Air, and the *Lacryma Batavica* does as much upon breaking its ſmall End.

Whereas an Alkali is a ſpongious Body filled with the igneous Matter, and an Acid are Points proportioned to theſe Pores; theſe ought to be regarded as ſo many Pegs or Pins, which enter into the Holes on the Surface of the Alkali, and fill them up exactly: Whereby the igneous Matter is impriſoned; and by the preceding Principle it burſts the alcaline Globule with Noiſe, and ſcatters around the acid Pegs, in the ſame manner as it burſt the Glaſs-Drop.

A Mixture of an alkaline and acid Liquor being compoſed of an infinite Number of ſuch Particles that burſt and broke to Pieces, the Liquor muſt take up more room, or ſwell. The Particles of Air therein contained, being toſſed about by all thoſe little Exploſions, together with the neutral Liquors, which are a Vehicle to the Salts, form the Scum or Froth; and the igneous Matter, which gets out of the Alkali's, and is agitated by the Shocks of all theſe Exploſions, produces Heat, drags with it the aqueous and other volatile Particles, which form the Steam.

Yet there are cold Fermentations, becauſe then, either the Motion of the Particles of Fire, and their *Fracas*, is inconſiderable; or becauſe theſe Particles fly off eaſily by a direct Motion. Moreover, at this Day that we have it in our Power to be convinced, that the *Brush* or Stream of electric Matter is very

cold, nobody will be ſurpriſed, that a Stream of the Matter of Fire may produce Cold.

If all the alcalious Corpuſcles burſted at once, the Fermentation would laſt but an Inſtant: But as the acid Liquor requires a certain Space of Time, to penetrate the whole alcaline Liquor, and fill the Pores of the alcalious Corpuſcles, the Fermentation is performed ſucceſſively in a certain Number of Corpuſcles at a time, until they are all broken: And this Succeſſion conſtitutes the Duration of the Fermentation; which ceaſes when there are none of the Alkali's left entire.

Theſe Principles not only ſerve to explain the Fermentation which reſults from the Mixture of Acids and Alkali's, but alſo almoſt all the Motions of this Kind, which are occaſioned by the Mixture or Penetration of two or more Subſtances.

For Example; Lime, which we have mentioned above as a Body filled with the Matter of Fire, and which produces an Effervescence capable of lighting Sulphur, if Water be thrown on it; Lime, I ſay, produces this Effect, only becauſe the Particles of Water, which enter into its Pores, have a Tendency to ſhut up the igneous Particles more cloſely. It is by a Mechaniſm entirely ſimilar, that *Homberg*'s Phoſphorus kindles into Flame, upon being expoſed to the Air: 'Tis upon this Principle likewiſe, that a Mixture of Spirit of Wine and Water acquires a new Degree of Heat; and ſo of other Phænomena of this Nature.

——— Le Cat.

XVII.