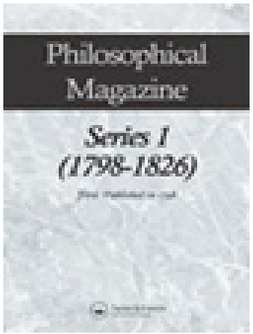

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LXXXV. Some observations and experiments on the papyri found in the ruins of Herculaneum

Sir Humphry Davy Bart. P.R.S.

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the formula derived from the first and most simple hypothesis relating to the constitution of the atmosphere, and that obtained by the last effort of scientific skill; and this is a coincidence which it is surely both curious and instructive to mark. J. I.

Erratum.—In the last Magazine, p. 342, 16th line from the top, the factor sin A is wanting in the value of r.

LXXXV. *Some Observations and Experiments on the Papyri found in the Ruins of Herculaneum. By Sir* HUMPHRY DAVY, *Bart. P.R.S.**

In a paper, intended for private circulation only, on the MSS. found in the excavations made at Herculaneum, but which was published, by mistake, in the Journal of Science and the Arts, I have described, in a general manner, the circumstances which led me to make experiments on these remains, and mentioned some of my first observations on this subject. Mr. Hamilton, to whom this communication was sent, entered into my views with all that ardour for promoting the progress of useful knowledge which so peculiarly belongs to his character; and on his representation of them, the Earl of Liverpool and Viscount Castlereagh, with the greatest liberality, placed at my disposal such funds as were requisite for paying the persons whom it was necessary to employ in trying new chemical methods of unrolling the MSS. and for examining and preserving them when unrolled; and His present Majesty, then Prince Regent, graciously condescended to patronize the undertaking.

In this communication, I shall do myself the honour of laying before the Royal Society an account of all that I have been able to do on this subject; namely, first, a detail of my early experiments in England on fragments of papyri, which induced me to believe that chemistry might afford considerable assistance towards unrolling the MSS. Secondly, a description of the rolls in the Museum at Naples, and of some analytical experiments I made upon them. Thirdly, a detail of the various chemical processes carried on in the Museum at Naples on the MSS., and of the reasons which induced me to renounce my undertaking before it was completed. And lastly, some general observations on the MSS. of the ancients.

I trust these matters will not be found wholly devoid of interest by the Society, and that they will excuse some repetitions of what I have stated in the Report before referred to, as they are necessary for a complete elucidation of the subject.

* From the Transactions of the Royal Society for 1821, Part II.

1st. *An*

1st. *An Account of some Experiments made in England on Fragments of Papyri in* 1818.

In examining, chemically, some fragments of a roll of papyrus found at Herculaneum, the leaves of which adhered very strongly together, I found that it afforded, by exposure to heat, a considerable quantity of gaseous matter, which was principally inflammable gas, and when acted on by muriatic or nitric ether, it coloured them; and when it was exposed to heat after the action of these fluids, there was an evident separation of the leaves of the MS.

Chlorine and iodine, it is well known, have no action upon pure carbonaceous substances, and a strong attraction for hydrogen; and it occurred to me, that these bodies might with propriety be used in attempting to destroy the matter which caused the adhesion of the leaves, without the possibility of injuring the letters on the papyri, the ink of the ancients, as it is well known, being composed of charcoal.

Having through the polite assistance of Sir Thomas Tyrwhitt procured some fragments of papyri on which Dr. Sickler, and some on which Dr. Hayter had operated, and by the kindness of Dr. Young a small portion of a MS. which he had himself unsuccessfully tried to unroll, I made some experiments upon them, by exposing them to the action of chlorine and the vapour of iodine, heating them gently after the process. These trials all afforded more or less hopes of success. When a fragment of a brown MS. in which the layers were strongly adherent, was placed in an atmosphere of chlorine, there was an immediate action, the papyrus smoked and became yellow, and the letters appeared much more distinct; and by the application of heat the layers separated from each other, giving off fumes of muriatic acid. The vapour of iodine had a less distinct action, but still a sensible one; and it was found that by applying heat alone to a fragment in a close vessel filled with carbonic acid or the vapour of ether, so as to raise the heat very gradually, and as gradually to lower it, there was a marked improvement in its texture, and it was much more easily unrolled.

Even in these preliminary trials, I found that it was necessary to employ only a limited and small quantity of chlorine, too large a quantity injuring the texture of the layer, and decomposing the earths which it contained; and that the action of heat was much more efficacious when the MS. had previously been exposed to chlorine, as the muriatic acid vapour formed greatly assisted the separation of the leaves, and a smaller degree of heat was required. But in all the trials, I found the success absolutely depended upon the manner in which the temperature

perature was regulated. When the fragment was too rapidly heated, the elastic fluid disengaged usually burst the folds of the MS.; and when the heat was lowered too suddenly, the layers sometimes split in irregular parts, probably from the sudden contraction consequent on quick cooling.

From the products of the distillation of these fragments, which were water, acetous acid, ammonia, carbonic acid, and much inflammable gas, I inferred that the papyri to which they belonged must contain much undecomposed vegetable matter, and could not be purely carbonaceous; but as there were great differences in the appearances even of the few papyri in England, which had been presented to His Majesty George IV. when Prince of Wales, an opinion on this subject was more likely to be correct when formed after an examination not only of all the MSS. found at Herculaneum, but likewise of the circumstances of the excavations made there; and I had an opportunity, during the time I remained at Naples, in two successive winters, to satisfy my mind on this subject, and to obtain the information which will be given in the next section.

2dly. *On the State of the MSS. found at Herculaneum.*

The persons who have the care of the MSS. found at Herculaneum state that their original number was 1696, and that 431 have been operated upon or presented to foreign governments, so that 1265 ought to remain; but amongst these, by far the larger proportion are small fragments, or specimens so injured and mutilated that there is not the least chance of recovering any portion of their contents; and when I first examined the rolls in detail in January 1819, it did not appear to me that more than from 80 to 120 offered proper subjects for experiments; and this estimate, as my researches proceeded, appeared much too high. These MSS. had been objects of interest for nearly 70 years; the best had long ago been operated upon, and those remaining had not only undergone injuries from time, but likewise from other causes, such as transport, rude examination, and mutilations for the purpose of determining if they contained characters.

The appearances of different rolls were extremely various. They were of all shades of colours from a light chesnut brown to a deep black; some externally were of a glossy black, like jet, which the superintendants called "varnished;" several contained the umbilicus or rolling stick in the middle converted into dense charcoal. I saw two or three specimens of papyri which had the remains of characters on both sides, but in general one side only was written upon. In their texture they were as various as in their colours; the pale brown ones in general presented only a kind of skeleton of a leaf, in which the earthy matter was nearly

nearly in as large a proportion as the vegetable matter, and they were light, and the layers easily separated from each other. A number of darker brown ones, which, from a few characters discovered in opening them, appeared to be Latin MSS., were agglutinated as it were into one mass; and when they were opened by introducing a needle between the layers, spots or lines of charcoal appeared where the folds had been, as if the letters had been washed out by water, and the matter of which they were composed deposited on the folds. Amongst the black MSS. a very few fragments presented leaves which separated from each other with considerable facility, and such had been for the most part operated upon; but in general the MSS. of this class were hard, heavy, and coherent, and contained fine volcanic dust within their folds. Some few of the black and darker brown MSS., which were loose in their texture, were almost entirely decayed, and exhibited on their surface a quantity of brown powder.

The persons to whom the care of these MSS. is confided, or who have worked upon them, have always attributed these different appearances to the action of fire, more or less intense, according to the proximity of the lava, which has been imagined to have covered the part of the city in which they were found: but this idea is entirely erroneous, that part of Herculaneum being, as I satisfied myself by repeated examinations, under a bed of tufa formed of sand, volcanic ashes, stones, and dust, cemented by the operation of water (probably at the time of its action in a boiling state). And there is great reason to conclude, that the different states of the MSS. depend upon a gradual process of decomposition: the loose chesnut ones probably not having been wetted, but merely changed by the re-action of their elements, assisted by the operation of a small quantity of air; the black ones, which easily unroll, probably remained in a moist state without any percolation of water; and the dense ones, containing earthy matter, had probably been acted on by warm water, which not only carried into the folds earthy matter suspended in it, but likewise dissolved the starch and gluten used in preparing the papyrus and the glue of the ink, and distributed them through the substance of the MSS., and some of these rolls had probably been strongly compressed when moist in different positions.

The operation of fire is not at all necessary for producing such an imperfect carbonization of vegetable matter as that displayed by the MSS.: thus, at Pompeii, which was covered by a shower of ashes that must have been cold, as they fell at a distance of seven or eight miles from the crater of Vesuvius, the wood of the houses is uniformly found converted into charcoal; yet the colours

lours on the walls, most of which would have been destroyed or altered by heat, are perfectly fresh, and where papyri have been found in these houses, they have appeared in the form of white ashes, as of burnt paper; an effect produced by the slow action of the air penetrating through the loose ashes, and which has been impeded or prevented in Herculaneum by the tufa, which, as it were, has hermetically sealed up the town, and prevented any decay, except such as occurs in the spontaneous decomposition of vegetable substances exposed to the limited operation of water and air; for instance, peat and Bovey coal.

The results of the action of heat upon the different specimens of the papyri, proved likewise, that they had never before been exposed to any considerable degree of temperature.

Various specimens of papyri were heated to dull redness in a small covered crucible of platinum to which air had no access. Some of the chesnut and most perfect specimens lost nearly half their weight, and the very black ones, and those containing the largest quantity of white ashes, all lost more than one-third, as the following results, selected from a number, will show:

No. 1. 100 parts of a pale chesnut papyrus lost 45 parts.
No. 2. 100 parts of a decomposed papyrus, chesnut-coloured, but darker, lost .. .. 43·
No. 3. 100 parts of a very black papyrus, lost .. 42·
No. 4. 100 parts of a pale papyrus, extremely loose in texture and partly converted into white ashes, lost .. .. 41·
No. 5. 100 parts of another of the same kind lost .. .. 38·

When the whole of the carbonaceous and vegetable matter of the papyrus was destroyed by slow combustion, the white ashes remaining, which were principally carbonate of lime and lime, proved to be from 1-16th to 1-20th of the original weight of the papyrus; and in those specimens which were most dense, and that contained a white powder, the proportion of ashes was greater, and a larger quantity was insoluble in acids.

Ammonia was found in the products of all the papyri that I distilled, but least in those which contained no distinct characters; from which it is probable that it arose principally from decomposed glue used in the manufacture of the ink, and which had been principally dissolved and carried off in those papyri which had been most exposed to the action of water.

I ascertained, that what the Neapolitans called varnish, was decomposed skin, that had been used to infold some of the papyri, and which by chemical changes had produced a brilliant animal carbonaceous substance; this substance afforded abun-

dance of ammonia by distillation, and left ashes containing much phosphate of lime.

3dly. *An Account of the Experiments on Papyri made in the Museum at Naples.*

Only one method, and that a very simple mechanical one, has been adopted for unrolling the MSS. It was invented by Padre Piaggi, a Roman, and consists in attaching thin animal membrane by a solution of glue to the back of the MSS. and carefully elevating the layers by silk threads when the glue is dry.

In considering this method in its general application, some circumstances occurred to me which afforded an immediate improvement. A liquid solution of glue had been used, which, when the texture of the MSS. was loose or broken, penetrated through three or four layers, and these, when the glue dried, separated together. To obviate this objection, I mixed the solution of glue with a sufficient quantity of alcohol to gelatinize it; and a mixture of the jelly and the fluid being made and applied by a camel's hair brush, a film of jelly remained on the exterior of the surface of the leaf, which attached itself to the membrane.

The effect of the solution of glue applied in the ancient method, was always likewise to separate the layers, by expanding the imperfectly carbonized fibres. In the improvement I have mentioned, the alcohol, from its greater lightness, penetrated further into the papyrus, but produced its greatest effect immediately on the first layers.

I adopted in some cases ether, as an agent for assisting the separation of the layers; and it was always found very efficacious, whether it was necessary to remove a single layer, or several layers at a time, in order to discover if a roll contained characters. The ether was applied by a camel's hair brush lightly to the surface of the leaf, when its operation was intended to be merely on that leaf; and it was suffered to sink deeper according as more layers were to be separated; the mere circumstances of its evaporation, which in some cases I assisted by heat, tended to detach the layers. For the black MSS. I employed sulphuric ether, and for the brown ones muriatic or nitric ether in their impure states, *i. e.* mixed with much alcohol.

No artificial modes had been employed by the Neapolitans for drying the papyrus in the operation of attaching the membrane, and no means, except mechanical ones, of detaching it after it was dried.

By throwing a stream of air gradually warmed till it attained a temperature about that of boiling water upon the surface of the

the leaf, I succeeded not only in drying the layers with much greater rapidity, but likewise in separating them with more delicacy.

I tried different modes of heating the air to be thrown upon the papyrus, such as passing it in a spiral metallic tube through warm water or oil by a double bellows, and from a large bladder through a straight tube having a very fine orifice, and heated by a copper ball surrounding the body of the tube, and exposed to burning charcoal; which last method, from its simplicity, I found the one best fitted to the Neapolitan operators. By sending the stream of air from a greater or smaller distance, so that it mixed with more or less cold air, the degree of temperature applied was regulated at pleasure. It was always found necessary to suffer a few minutes to elapse after the membrane was attached, and then to begin with a very slight increase of temperature; as otherwise, by too sudden an application of heat, the membrane shrivelled before it became adherent, and the vapour suddenly raised destroyed its union with the papyrus; whereas, when the moisture was suffered to drain from the gelatinized glue, and the temperature was gradually raised, the expansion of the skin and the upper layer separated them perfectly from the lower layers, so that the unrolling was performed, as it were, by chemical means; and an operation, which hitherto had required some hours for its completion, was easily effected in from 30 to 40 minutes.

I tried several experiments, by substituting solution of resins in alcohol and of gums in water for the gelatinized solution; but none of them answered so well; the resins would not adhere with any tenacity to the membrane, and the gums, when dried, had not that flexibility which is an important character in the glue.

The alterations in the mode of applying and drying the membrane used to detach and preserve the leaves of MSS. capable of being unrolled, applied generally; I shall now mention the plans I adopted for the preparation of the MSS. for this operation.

MSS. in different states required a treatment of a directly opposite kind, which was to be modified according to circumstances. The pale chesnut-coloured MSS., covered partially with white ashes, were generally of a texture so loose, and had their layers so destroyed, that there was considerable danger of their falling into pieces by mere touching. The characters that remained in many of them were extremely distinct; and when a number of layers were taken up at once, it appeared as if they presented perfect columns of writing: but the fact is, the papyrus was full of holes, and each line was made up of letters from several dif-

ferent folds of the MS. When the process of unrolling these papyri was performed in the common way, the result obtained appeared, till it was examined minutely, a perfect column; but was in fact made up of the letters of different words. I endeavoured to obtain the fragments of a single leaf attached to a layer of membrane by applying a solution of caoutchouc in ether to the surface of a MS., so as to supply the parts of the leaf destroyed; but operating in this way, I obtained only a few characters, and never an entire word; so that, after various unsuccessful trials, I was obliged to give up the MSS. of this description as hopeless; more than 5-6ths of their contents probably being always destroyed, and that in so irregular a way as to leave no entire sentences, or even words.

On two brown MSS., which were firm in their texture, and had the appearance of peat, and the leaves of which would not separate by common means, I tried the experiment of heating, after they had absorbed a small quantity of chlorine; and I found that in both cases the leaves detached themselves from each other, and were easily unrolled; but these MSS. had been so penetrated by water, that there were only a few folds which contained words, and the letters were generally erased, and the charcoal which had composed them was deposited on the folds of the MSS.

Of the black MSS., of which the layers were perfect and easily separated, all the best specimens had been unrolled or operated upon, so that fragments only of this description remained. By assisting the operation of detaching the layers by muriatic ether and the other processes mentioned in page 426, many parts of columns were obtained from several of the fragments, by which some idea of their contents may be formed.

On the black compact and heavy MSS. which contained white earthy matter in their folds, I tried several experiments, with the hopes of separating them into single layers, both by the action of muriatic and nitric ether, and by the operation of chlorine and of weak hydrofluoric acid, assisted by heat; but generally the fibres of the papyrus had been so firmly cemented together, and so much earthy matter had penetrated them, that only a very imperfect separation could be obtained, and in parts where vestiges only of letters appeared, so that from MSS. of this kind only a few remains of sentences could be gained.

During the two months that I was actively employed in experiments on the papyri at Naples, I had succeeded, with the assistance of six of the persons attached to the Museum, and whom I had engaged for the purpose, in partially unrolling twenty-three MSS., from which fragments of writing were obtained,

tained, and in examining about 120 others, which afforded no hopes of success; and I should gladly have gone on with the undertaking, from the mere prospect of a possibility of discovering some better results, had not the labour, in itself difficult and unpleasant, been made more so by the conduct of the persons at the head of this department in the Museum. At first, every disposition was shown to promote my researches; for the papyri remaining unrolled were considered by them as incapable of affording any thing legible by the former methods, or, to use their own word, *disperati;* and the efficacy and use of the new processes were fully allowed by the Svolgatori or unrollers of the Museum; and I was for some time permitted to choose and operate upon the specimens at my own pleasure. When, however, the Reverend Peter Elmsley, whose zeal for the promotion of ancient literature brought him to Naples for the purpose of assisting in the undertaking, began to examine the fragments unrolled, a jealousy, with regard to his assistance, was immediately manifested; and obstacles, which the kind interference of Sir William A'Court was not always capable of removing, were soon opposed to the progress of our inquiries; and these obstacles were so multiplied, and made so vexatious towards the end of February, that we conceived it would be both a waste of the public money, and a compromise of our own characters, to proceed.

4thly. *Some general Observations.*

The Roman MSS. found in the Museum, are in general composed of papyrus of a much thicker texture than the Greek ones, and the Roman characters are usually larger, and the rolls much more voluminous; the characters of the Greek MSS., likewise, with a few exceptions, are more perfect than those of the Latin ones.

From the mixture of Greek characters in several fragments of Latin MSS., and from the form of the letters and the state of decomposition in which they are found, it is extremely probable that they were of a very ancient date when buried.

I looked in vain amongst the MSS. and on the animal charcoal surrounding them, for vestiges of letters in oxide of iron; and it would seem from these circumstances, as well as from the omission of any mention of such a substance by Pliny, that the Romans, up to his period, never used the *ink of galls and iron* for writing: and it is very probable, that the adoption of this ink, and the use of parchment, took place at the same time. For the ink composed of charcoal and solution of glue can scarcely be made to adhere to skin; whereas the free acid of the chemical

cal ink partly dissolves the gelatine of the MSS., and the whole substance adheres as a mordant; and in some old parchments, the ink of which must have contained much free acid, the letters have, as it were, eaten through the skin, the effect being always most violent on the side of the parchment containing no animal oil.

The earliest MSS. probably in existence on parchment, are those codices rescripti, discovered by Monsignore Mai, in the libraries of Milan and Rome. Through his politeness I have examined these MSS., particularly that containing some of the books of *Cicero de Republica*, and which he refers to the second or third century. From the form of the columns, it is very probable that they were copied from a papyrus. The vegetable matter which rendered the oxide of iron black is entirely destroyed, but the peroxide of iron remains; and where it is not covered by the modern MSS., the form of the letter is sufficiently distinct. Monsignore Mai uses solution of galls for reviving the blackness. I have tried several substances for restoring colour to the letters in ancient MSS. The triple prussiate of potash, used in the manner recommended by the late Sir Charles Blagden, with the alternation of acid, I have found successful; but by making a weak solution of it with a small quantity of muriatic acid, and by applying them to the letters in their state of mixture with a camel's hair pencil, the results are still better.

It is remarkable, that no fragments of Greek, and very few only of Latin poetry, have been found in the whole collection of the MSS. of Herculaneum; and the sentences in the specimens we unrolled, in which Mr. Elmsley was able to find a sufficient number of words to infer their meaning, show that the works, of which they are the remains, were of the same kind as those before examined, and belonged to the schools of the Greek Epicurean philosophers and sophists.

Nearly 1000 columns of different works, a great part unrolled under the superintendance of Mr. Hayter, and at the expense of His present Majesty George IV., have been copied and engraved by the artists employed in the Museum; but from the characters of the persons charged with their publication, there is very little probability of their being, for many years, offered to the world; which is much to be regretted; for, though not interesting from their perfection as literary works, they would unquestionably throw much light upon the state of civilization, letters and science, of the age and country to which they belonged.

Should discoveries of MSS. at any future time be made at Herculaneum, it is to be hoped that the papyri will be immediately excluded from the atmosphere, by being put into air-tight cases, filled with carbonic acid after their introduction. There can

can be no doubt that the specimens now in the Museum were in a much better state when they were first discovered; and the most perfect even, and those the coarsest in their texture, must have been greatly injured during the 69 years that they have been exposed to the atmosphere. I found that a fragment of a brown MS. kept for a few weeks in a portion of air confined by mercury, had caused the disappearance of a considerable part of the oxygen, and the formation of much carbonic acid.

LXXXVI. *Remarks on Dr.* READE's *Paper on Refraction. By Mr.* CHARLES STARK, *of Portsmouth.*

To Dr. Tilloch.

SIR, — IN the Number of your Magazine for October, I observe a paper by Dr. Reade, on the subject of Refraction, wherein a very determined attempt seems to be made to overturn the whole doctrine of Dioptrics, and to explain all the phænomena of optics on the principle of reflection alone. If he should really succeed in the accomplishment of this design (which he seems to anticipate with no small degree of confidence), an important æra will, no doubt, be formed in the history of science, and an inevitable death blow given to those standard works on the subject, which have been so long adopted in our schools and universities. How far the Doctor is likely to succeed in effecting such a revolution, is my object here to inquire.

In the formation of any new theory, or in the determination of a general law in philosophy, such as the one under consideration, it may be presumed that the author, before publishing it to the world, would have observed the utmost degree of caution, not only in establishing the reasonableness of the hypothesis itself, but also in submitting it to the test of repeated and varied experiments, so as to be found not only consistent with itself, but successful in all its applications. In this respect, no theory has ever been employed, in any department of Natural Philosophy, with more complete success than that which Dr. R. is here endeavouring to explode. In reviewing the arguments, however, which he has brought forward in its refutation, and also those advanced in support of his own, it will require but little ingenuity of reasoning to show that his time and labour have been spent to very little purpose.

Dr. R. commences his paper by endeavouring to refute the explanation that is usually given of the common optical experiment of placing a piece of money at the bottom of an empty vessel, and its seeming to rise higher as water is poured into it. He objects to the common explanation by saying: "How can any