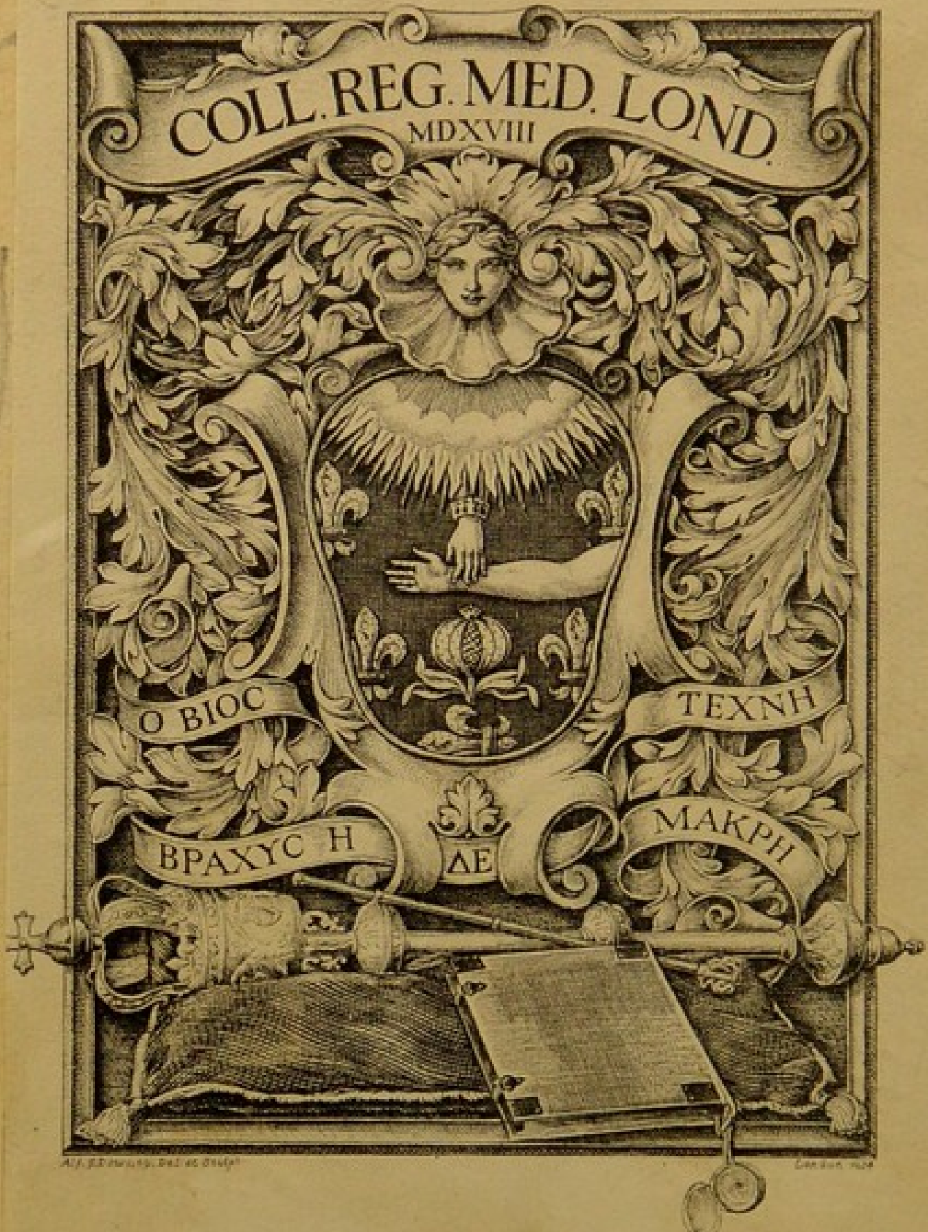
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# Experimental Reſearches

CONCERNING THE

# PHILOSOPHY

OF

# PERMANENT COLOURS.

VOL. I.

# Experimental Reſearches

CONCERNING THE

# PHILOSOPHY

OF

# PERMANENT COLOURS;

AND THE

## Beſt Means of producing them, by Dying, Callico Printing, &c.

By EDWARD BANCROFT, M.D.

FELLOW OF THE ROYAL SOCIETY, &c.

" Cet art (de la teinture) eſt un des plus utiles et des plus merveilleux
" qu'on connoiſſe; & ſi quelque un peut inſpirer un noble orgueil à
" l'homme, c'eſt celui là: non ſeulment il a procuré le moyen de
" ſuivre et d'imiter la nature dans la richeſſe & l'eclat des couleurs;
" mais il paroit l'avoir ſurpaſſé en donnant plus d'éclat, plus de fixité
" & plus de ſolidité aux couleurs fugaces & paſſageres dont elle a revetu
" tous les corps qui compoſent ce globe."

Chaptal, *Elémens de Chimie*, tom. iii. p. 185.

VOL. I.

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(SUCCESSORS TO MR. CADELL,) IN THE STRAND.

M DCC XCIV.

# PREFACE.

A Confiderable part of this Volume was printed early in the year 1792; but various interruptions have fince concurred in delaying its conclufion. A fecond Volume is intended to follow, and complete my prefent plan; the materials of which are nearly all provided, though I cannot expect that it will be publifhed until near the end of the enfuing year.

That and the prefent volume will contain the refults of many thoufands of experiments, and of much obfervation and reflection, during the fpace of twenty-five years, in which this fubject has been my principal occupation; and as it will probably continue to occupy a great part of my time, whilft life and health are prolonged to me, I may be allowed to hope, that future difcoveries will hereafter enable me to publifh at leaft one other volume as fupplementary to thefe, which are intended to convey all the knowledge I have hitherto acquired on this fubject.

The prefent volume comprehends what I have to offer concerning the different animal, vegetable, and mineral colours, and colouring matters of that claſs which I have denominated *ſubſtantive*, becauſe they do not depend upon any baſis or mordant, either for their permanency or their luſtre: and alſo what I have to communicate reſpecting the colouring matters of an *animal* nature, belonging to the other claſs or diviſion, which I have called *adjective* colours, becauſe they are capable of being enlivened and fixed only by being adjected or applied upon a ſuitable baſis: and it alſo contains ſuch of the *vegetable* adjective colouring matters as are uſed, or capable of being advantageouſly uſed, in producing the various ſhades of yellow.

The ſecond volume is intended to comprehend all the remaining adjective colours and colouring matters, particularly thoſe very intereſting ones which are derived from the tribe of *madders*, the different ſpecies of *gallium*, and other roots employed in Aſia, as well as in Europe, to produce permanent reds; the different red, purple, and other dying woods now in uſe, with many which never were uſed, at leaſt in Europe, except by myſelf; and alſo the different vegetable matters which become *black* by being combined with iron; reſpecting which I ſhall have many new and important facts to communicate. I ſhall alſo in the ſecond volume reſume and proſecute, as far as I may be able, ſome abſtruſe but intereſting inquiries relating to the cauſes which influence not only the production but the variations and decays of colours, of which indeed the preſent volume affords many intimations, though my final concluſions on this ſubject have been delayed for the reſults of particular experiments, which I have not hitherto been able to proſecute ſatisfactorily. And indeed, reſpecting ſome part of what I have been able to do in this intricate enquiry, I may ſay with M. Sennebier, "*je ne puis diſſimuler que j'ai vu varier mes expériences d'une maniere propre à me confondre; quoique je ſuiviſſe conſtamment les mêmes procédés, du moins en apparence, je dois le dire, j'ai vu des réſultats oppoſés.*" (Mems. Phyſico-Chyms. &c.) And perhaps there is none of thoſe who have been long engaged in chymical purſuits, to whom ſimilar difficulties and diſappointments have not occurred.

Nothing but a hope that this work may produce conſiderable public benefit could have induced me, amidſt other numerous avocations, thus to employ the time and attention which have been neceſſary to produce it. I feel, however, that it will be far, very far from deſerving the character of a perfect work, and, in truth, that chymical ſcience is far from having attained that ſtate which is neceſſary to perfection on this ſubject. The objects, and the knowledge required for a complete treatiſe on dying and callico printing, are indeed ſo various and extenſive, that what Sennebier has ſaid of ſuch a performance will always be true, " *Cet ouvrage ſeroit immenſe; il ne conſiſte pas en faits iſolés, qu'il ſuffit d'examiner ſéparément; c'eſt un enſemble prodigieux à créer, ſoit par la réunion des faits counus et de leurs applications, ſoit par la recherche des faits nouveaux,*" *&c.*

In arranging the objects of my preſent undertaking, I have adopted that plan which would, as I thought, beſt enable me to convey my ideas intelligibly, with the feweſt repetitions, and without ſeparating matters eſſentially connected to each other. In purſuing it, I have endeavoured to avoid minute deſcriptions of ſuch manual and mechanical operations of dying and callico printing, as are not connected with the principles of the art; becauſe artiſts know them already, and, to mere ſpeculative readers, a knowledge of them would be uſeleſs.

My Readers will ſee, that I have adopted the terms of the New Chymical Nomenclature, and

and alſo (with a very few exceptions) the principles to which it relates: and I have done this, not becauſe I conſider them as forming a perfect ſyſtem, or imagine that we are yet acquainted with all the minute and abſtruſe cauſes of chymical effects, but becauſe I conſider the new doctrines as according much better with facts than the old; and as being much better ſuited to become parts of a perfect ſyſtem, when ſucceſſive diſcoveries ſhall at length afford the means neceſſary to its attainment. And though there are ſome truly reſpectable chymiſts, whoſe minds, ſtrongly prepoſſeſſed by ideas and opinions formerly received, have not yet become acceſſible to the ſuperior evidence which ſupports the new ſyſtem; yet their number is continually diminiſhing, and, in a ſhort ſpace, the generation itſelf, to which thoſe of us belong, who either were, or continue to be, prejudiced on this ſubject, will *have paſſed away*; and, judging by the ſentiments of thoſe who are likely to ſtand foremoſt among our ſucceſſors, there can be no difficulty in foreſeeing which of theſe ſyſtems muſt prevail.

LONDON, *Auguſt* 25th, 1794.

The Reader is desired to correct the following more material Errors of the Press, *viz.*

| | | | |
|---|---|---|---|
| Page 16. | line 30. | *for* | Barthollet *read* Bertholet. |
| 38. | —— 24. | —— | cœlor *read* calor. |
| 62. | —— 19. | —— | diluted *read* dilated. |
| 97. | —— 12. | —— | Goquet *read* Goguet. |
| 97. | —— 24. | —— | arundinem *read* harundinum. |
| 115. | —— 16. | *after* | vital *add* the nitrous, or the fixed. |
| 137. | —— 29. | *for* | Quatrenere *read* Quatremere. |
| 160. | —— 24. | —— | Hallot *read* Hellot. |
| 160. | —— 30. | —— | forcé *read* foncé. |
| 166. | —— 6. | —— | Lord Verulum *read* Lord Verulam. |
| 171. | —— 4. | *of note.* | cortinem *read* cortinam. |
| 171. | —— 9. | —— | *after* digeret *add* eos. |
| 180. | —— 6. | *for* | sulphate of alum *read* sulphate of alumine. |
| 188. | —— 21. | —— | Luteolu *read* Luteola. |
| 215. | —— 25. | —— | what *read* that. |
| 215. | —— 4. | *of note.* | in o water *read* into water. |
| 225. | —— 22. | —— | spissed *read* spissated. |
| 229. | —— 30. | —— | aubicular *read* orbicular. |
| 263. | —— 6. | *of note.* | celatant *read* éclatant. |
| 299. | —— 11. | —— | than *read* by. |
| 254. | —— 16 & 24. | —— | acetite *read* acetite. |

# EXPLANATIONS

OF

# NEW TERMS, uſed in this Volume.

## A.

| | |
|---|---|
| ACETATES. | Salts formed by the combination of the *acetic* acid, or radical vinegar, with different baſes. |
| Acetate of copper. | Copper combined with the acetic acid. |
| Acetate of iron. | Iron combined with the acetic acid. |
| Acetic acid. | Radical vinegar. |
| Acetites. | Salts formed by the combination of the acetous acid, or diſtilled vinegar, with different baſes. |
| Acetite of alumine. | Alumine, or earth of alum, combined with the acetous acid. |
| Acetite of biſmuth. | Biſmuth combined with the acetous acid. |
| Acetite of copper. | Copper combined with the acetous acid. |
| Acetite of iron. | Iron combined with the acetous acid. |
| Acetite of lead. | Lead combined with the acetous acid. |
| Acetite of magneſia. | Magneſia combined with the acetous acid. |
| Acetous acid. | Diſtilled vinegar. |
| Acidulous arſeniate of pot-aſh. | Macquer's arſenical neutral ſalt: pot-aſh, or vegetable alkali, united to the arſenic acid; in which the pot aſh not being ſufficient |

| | |
|---|---|
| | ſufficient to neutralize this acid, the latter predominates, and the ſalt is therefore called acidulous. |
| Adjective colours or colouring matters. | Colours or colouring matters, which acquire their luſtre and permanency by being adjected or applied upon a ſuitable baſis. |
| Ammoniac. | Cauſtic volatile alkali. Volatile ſpirit of ſal ammoniac. |
| Ammoniates. | Combinations of ammoniac with different baſes. |
| Ammoniate of copper. | Copper combined with ammoniac. |
| Arſeniates. | Salts formed by the combination of the arſenic acid with different baſes. |
| Arſenic acid. | The acid which is obtained from arſenic. |
| Azote. | Phlogiſticated air of Prieſtley and others; the baſis of the nitrous acid; and hence alſo called nitrogene by Chaptal, &c. |

B.

| | |
|---|---|
| Barytes. | Earth of ponderous ſpar. |

C.

| | |
|---|---|
| Caloric. | Matter or ſubſtance of heat. Latent heat. |
| Carbonates. | Combinations of the carbonic acid with different baſes. |
| Carbonate of ammoniac. | Ammoniac united to the carbonic acid. Concrete, or mild volatile alkali. |
| Carbonate of lime. | Chalk. Aerated calcareous earth. |
| Carbonate of potaſh. | Mild fixed vegetable alkali. Salt of tartar. |
| Carbonate of ſoda. | Fixed mineral alkali. |
| Carbone. | Pure charcoal, or the baſis of charcoal. |
| Carbonic acid. | The acid obtained from carbone, in the form of an elaſtic fluid or gaz. Commonly called fixed air. |

Citrates.

| | |
|---|---|
| Citrates. | Salts formed by the combination of the citric acid, or acid of lemons with different bafes. |
| Citrate of alumine. | Alumine united to citric acid. |
| Citrate of tin. | Tin diffolved by, or combined with, citric acid. |
| Citric acid. | Acid of lemons. |

F.

| | |
|---|---|
| Fluates. | Salts formed by the union of the fluoric acid with different bafes. |
| Fluate of tin. | Tin combined with fluoric acid. |
| Fluoric acid. | Spathofe acid. |

G.

| | |
|---|---|
| Gaz or gas. | An elaftic or aëriform fluid. |

H.

| | |
|---|---|
| Hydrogenous gaz. | Inflammable air. |

M.

| | |
|---|---|
| Muriates. | Salts formed by the combination of the muriatic acid with different bafes. |
| Muriate of alumine. | Alumine combined with muriatic acid. |
| Muriate of ammoniac. | Ammoniac combined with muriatic acid. |
| Muriate of antimony. | Antimony combined with muriatic acid. |
| Muriate of barytes. | Barytes combined with muriatic acid. |
| Muriate of bifmuth. | Bifmuth combined with muriatic acid. |
| Muriate of cobalt. | Cobalt combined with muriatic acid. |
| Muriate of copper. | Copper combined with muriatic acid. |
| Muriate of iron. | Iron combined with muriatic acid. |
| Muriate of lead. | Lead combined with muriatic acid. Horned lead. |
| Muriate of lime. | Lime combined with muriatic acid. |
| Muriate of magnefia. | Magnefia combined with muriatic acid. |

Muriate

| | |
|---|---|
| Muriate of mercury. | Mercury combined with muriatic acid. |
| Muriate of ſilver. | Silver combined with muriatic acid. |
| Muriate of ſoda. | Soda combined with muriatic acid. Common ſea ſalt. |
| Muriate of tin. | Tin combined with muriatic acid. |
| Muriate of zinc. | Zinc combined with muriatic acid. |
| Muriatic acid. | Acid of ſea ſalt. Marine acid. |
| Murio-nitrates. | Salts formed by the combination of the muriatic and nitric acids with different baſes; the muriatic acid being in the greateſt proportion. |
| Murio-nitrate of tin. | Solution of tin, by the muriatic and nitric acids. |
| Murio-ſulphates. | Combinations of the muriatic and ſulphuric acids with different baſes; the muriatic acid being in the greateſt proportion. |
| Murio-ſulphate of biſmuth. | Solution of biſmuth, by the muriatic and ſulphuric acids. |
| Murio-ſulphate of tin. | Solution of tin, by the muriatic and ſulphuric acids. |
| Murio-ſulphate of zinc. | Solution of zinc, by the muriatic and ſulphuric acids. |
| Murio-tartrites. | Combinations of the muriatic and tartareous acids with different baſes; the muriatic acid being in the greateſt proportion. |
| Murio-tartrite of tin. | Tin diſſolved by the muriatic and tartareous acids. |

## N.

| | |
|---|---|
| Nitrates. | Salts formed by the combination of the *nitric* acid with different baſes. |
| Nitrate of alumine. | Alumine combined with nitric acid. |
| Nitrate of antimony. | Antimony combined with nitric acid. |
| Nitrate of barytes. | Barytes combined with nitric acid. |
| Nitrate of biſmuth. | Biſmuth combined with nitric acid. |
| Nitrate of cobalt. | Cobalt combined with nitric acid. |
| Nitrate of copper. | Copper combined with nitric acid. |
| Nitrate of iron. | Iron combined with nitric acid. |

Nitrate

| | |
|---|---|
| Nitrate of lead. | Lead combined with nitric acid. |
| Nitrate of lime. | Lime combined with nitric acid. |
| Nitrate of magneſia. | Magneſia combined with nitric acid. |
| Nitrate of manganeſe. | Manganeſe combined with nitric acid. |
| Nitrate of mercury. | Mercury combined with nitric acid. |
| Nitrate of nickle. | Nickle combined with nitric acid. |
| Nitrate of pot-aſh. | Pot-aſh combined with nitric acid. Nitre or ſaltpetre. |
| Nitrate of ſilver. | Silver combined with nitric acid. |
| Nitrate of tin. | Tin combined with nitric acid. |
| Nitrate of zinc. | Zinc combined with nitric acid. |
| Nitric acid. | Dephlogiſticated nitrous acid. Colourleſs aqua-fortis or acid of nitre, in which the baſis or azotic part is fully ſaturated with oxygene. |
| Nitrites. | Combinations of the *nitrous* acid with different baſes. |
| Nitrous acid. | Phlogiſticated nitrous acid. Red or ſmoking ſpirit of nitre, in which the azotic baſis is not fully ſaturated with oxygene. |
| Nitro-muriates. | Salts, formed by the combination of the nitric and muriatic acids with different baſes, in which the nitric acid is in the greateſt proportion. |
| Nitro-muriate of antimony. | Antimony combined with nitric and muriatic acids. |
| Nitro-muriate of biſmuth. | Biſmuth combined with nitric and muriatic acids. |
| Nitro-muriate of gold. | Gold combined with nitric and muriatic acids. |
| Nitro-muriate of platina. | Platina combined with nitric and muriatic acids. |
| Nitro-muriate of tin. | Tin combined with nitric and muriatic acids. |
| Nitro-muriatic acid. | A mixture of the nitric and muriatic acids; formerly called aqua regia. |

O.

| | |
|---|---|
| Oxide or oxyd. | The combination of a metal with oxygene in a ſolid form, formerly called Calx. |

Oxygene.

| | |
|---|---|
| Oxygene. | The basis of pure or vital air. The aërial acidifying principle. |
| Oxygenated muriatic acid. | Muriatic acid, with an addition of oxygene; formerly called dephlogisticated marine acid. |
| Oxygenated muriatic acid gaz. | The oxygenated muriatic acid combined with caloric, by which it is raised into the form of an elastic fluid. |

P.

| | |
|---|---|
| Phosphates. | Salts formed by the combination of the phosphoric acid with different bases. |
| Phosphate of tin. | Tin combined with phosphoric acid. |
| Pot-ash. | Caustic vegetable alkali. |
| Prussian or Prussic acid. | The acid of Prussian blue. |
| Prussiates. | Combinations of the Prussic acid with different bases. |
| Prussiate of ammoniac. | Ammoniac combined with Prussic acid, or colouring principle of Prussian blue. |
| Prussiate of lime. | Lime combined with Prussic acid. |
| Prussiate of pot-ash. | Pot-ash combined with Prussic acid. |
| Prussiate of soda. | Soda combined with Prussic acid. |
| Pyroligneous acid. | The empyreumatic acid, obtained by distillation from wood, &c. |
| Pyrolignites. | Combinations of the pyroligneous acid with different bases. |
| Pyrolignite of iron. | Iron combined with pyroligneous acid. |
| Soda. | Caustic fossil alkali. |
| Substantive colouring matter. | Colouring matter which requires no basis or mordant to give it lustre or permanency. |
| Sulphates. | Salts formed by the combination of the sulphuric acid with different bases. |
| Sulphate of alumine. | Alumine combined with sulphuric acid. Common alum. |
| Sulphate of barytes. | Barytes combined with sulphuric acid. |
| Sulphate of bismuth. | Bismuth combined with sulphuric acid. |

| | |
|---|---|
| Sulphate of copper. | Copper combined with ſulphuric acid. Blue vitriol. |
| Sulphate of indigo. | Indigo combined with ſulphuric acid. |
| Sulphate of iron. | Iron combined with ſulphuric acid. Green vitriol, or copperas. |
| Sulphate of lime. | Lime combined with ſulphuric acid. Selenite. |
| Sulphate of magneſia. | Magneſia combined with ſulphuric acid. Epſom ſalt. |
| Sulphate of manganeſe. | Manganeſe combined with ſulphuric acid. |
| Sulphate of pot-aſh. | Pot-aſh combined with ſulphuric acid. Vitriolated tartar. |
| Sulphate of tin. | Tin combined with ſulphuric acid. |
| Sulphate of zinc. | Zinc combined with ſulphuric acid. |
| Sulphure or ſulphuret of antimony. | Combination of ſulphur with antimony; formerly called crude antimony. |
| Sulphure of arſenic. | Combination of ſulphur with arſenic. |
| Sulphure of pot-aſh. | Sulphur united to pot-aſh; or liver of ſulphur. |

T.

| | |
|---|---|
| Tartaro-nitrates. | Combinations of the tartareous and nitric acids with different baſes; the tartareous acid being in the greater proportion. |
| Tartaro-nitrate of tin. | Tin combined with the tartareous and nitric acids. |
| Tartaro-ſulphates. | Combinations of the tartareous and ſulphuric acids with different baſes; the tartareous acid being in the greater proportion. |
| Tartaro-ſulphate of tin. | Tin combined with the tartareous and ſulphuric acids. |
| Tartrites. | Combinations of the tartareous acid with different baſes. |
| Tartrite of alumine. | Alumine combined with tartareous acid. |
| Tartrite of tin. | Tin combined with tartareous acid. |

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*Of the Properties and Uſes of Juglans Alba or American Hiccory; of the Weld Plant, Fuſtic, and other Vegetables, affording Yellow Adjective Colouring Matters.*

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# APPENDIX,

CONTAINING,

# INTRODUCTION.

THE Great Author of Nature having allotted and employed colours, as means of diſtinguiſhing and adorning the various productions of his power, wiſdom, and goodneſs, has alſo endowed ſome animals, and particularly man, not only with perceptions of the differences of colours, but alſo of the beauty ariſing from them and their various combinations: and it is in conſequence of theſe perceptions that mankind, even in the rudeſt ſtates of human exiſtence, have been found to manifeſt great admiration and deſire for ornaments depending on gaudy and varied colours; which, at firſt, naked ſavages generally applied to their ſkins, and afterwards to their garments, when they had approached ſo far towards civilization as to manufacture and wear cloathing. To theſe motives, and to the rude trials induced by them, even in remote ages, the arts of dying and callico printing undoubtedly owe their origin.

It will appear in the following chapters, that colouring matters are of two very diſtinct claſſes; one which requires no baſis or mordant to fix it upon other objects, and which I have therefore denominated *ſubſtantive* colouring matter; and the other, whoſe durability depends chiefly, if not wholly, upon the interpoſition of ſome baſis, and

and which, for that reafon, I have called *adjective* colouring matter; and as, among colouring matters, thofe of the adjective clafs would naturally prefent themfelves in the greateft abundance, and be applied without any means to render them permanent, (becaufe it would require numerous trials, and a concurrence of many fortunate accidents to difcover the ufe of any bafis or mordant,) we may reafonably conclude, that moft of the ftains or dyes firft applied to different fubftances would in all countries have been fugitive. Such, according to Pliny, were thofe of the Gauls *, and fuch have been the greateft part of thofe employed by the uncivilized inhabitants of all the newly-difcovered countries: and we may therefore confider the difcovery of the effects of bafes or mordants, and particularly of alum, in fixing adjective colouring matters, as a moft important event in the hiftory of dying. When or where this difcovery was firft made cannot be afcertained; there is, however, good reafon to believe, that alum, and probably iron, (which are the principal bafes of modern callico printing,) were employed by the Egyptians in producing thofe effects which are defcribed by Pliny, L. xxxv. § 42; becaufe

* "*Tranfalpina Gallia herbis Tyrium atque conchilium tingit, omnefque alios colores—Sed culpa non ablui ufu.*" Lib. xxii. § 3. This however was not always the cafe in other countries: Herodotus mentions a people living on the borders of the Cafpian fea, who by bruifing the leaves of a particular tree, and mixing them with water, obtained a colour by which they afterwards painted or ftained their garments with the figures of animals, &c. which figures, he adds, water could not efface; on the contrary, they remained until the cloth was worn out, as if they had been woven therein. Book Clio. c. c. iii.

they

they resemble others which callico printers now obtain by these means, and which at this time they cannot obtain by any other, even with all the knowledge since acquired: and, in the seventh chapter of this volume, facts and reasons are adduced, to prove that the Egyptians borrowed this art from Hindostan, where it appears to have subsisted for more than two thousand years, probably with very little if any variation or improvement during that long space of time: and if we may judge of the means formerly employed in Hindostan for dying or staining callicoes by those which were found to be in use for that purpose, when the nations of Europe first went thither by the Cape of Good Hope, we may safely conclude, that solutions of alum and of iron must have been the mordants employed in fixing their adjective colours. Hindostan appears also to have been the country where that wonderful substantive colouring matter called indico, or indigo, was first produced. The uncivilized inhabitants of other countries indeed have found out ways of obtaining substantive blue colouring matters, very nearly resembling that of indigo, from different plants, particularly from the isatis tinctoria Linn., or woad, and from the genipa Americana Linn., but they obtained these matters in a liquid form only. The people of India however went farther; they precipitated and collected in a dry solid form the colouring matter of indigo, and, what must have been a matter of much greater difficulty, they afterwards discovered the means of dissolving it, and rendering it capable of being permanently fixed upon the substances intended to be stained or dyed with it; an effect which the Greeks and

Romans do not appear to have ever produced, though they knew how to powder and apply indigo as a paint.

From the fifth volume of that extenſive Work intituled, " Memoires concernants l'Hiſtoire, les Sciences, les Arts, les Moeurs, &c. des Chinois," it appears that wool was never worn in China but as a ſubſtitute for fur, and that cotton and ſilk, being the only ſubſtances ever dyed by the inhabitants, received all their colours from vegetable tingent matters; that theſe colours were principally red, blue, violet, and what is called a woad colour; and that under the three firſt dynaſties, the buſineſs of dying was chiefly practiſed by the female part of each family, for its own particular uſe: and it probably continued to be practiſed without any thing like principle or ſcience until near the end of the ſeventh century, when the Chineſe, diſcarding their own, borrowed the art and means of dying which were then in uſe among the Indians and Perſians: and it is ſaid, that alum and copperas, which the Chineſe did not uſe before, were among the means ſo borrowed; a fact which renders it probable that there was little, if any thing, in the Chineſe art of dying, of which the loſs need now be regretted.

It appears however that, long before this time, a knowledge of the uſes of alum and of iron in dying, had ſpread from Hindoſtan and Perſia weſtward to Egypt, and thence to Greece and Rome. Bergmann indeed, (de Confect. Alum,) and after him Beckmann, (in the Göttingen Memoirs,) have repreſented the alum of the antients

antients as different from the cryſtallized ſalt ſo called by the moderns; and have ſuppoſed, that the varieties of alum mentioned by Dioſcorides were ſtalactites, containing but little alum, and conſiſting chiefly of calcareous earth, which, in certain proportions, will hereafter appear to be a very uſeful addition for moſt of the colours depending on an aluminous baſis. Nature however does produce ſome, though but little cryſtallized alum, particularly in Egypt and ſome parts of Aſia; and it probably was in this ſtate that its good effects in dying had been firſt obſerved, before mankind were led to the means and operations ſince employed for ſeparating and collecting it from the various aluminous ores. Bergmann ſays, that "the factitious ſalt which "is now called alum, was firſt diſcovered in "the Eaſtern countries;" and that "among "the moſt early works eſtabliſhed for the pre-"paration of alum, we may juſtly number that "of *Roccho*, a city in Syria, now called Edeſſa: "hence the appellation of roch alum." See vol. I. p. 339. of the Engliſh Tranſlation of his Eſſays. He adds, that "Bartholomew Perdix "or Pernix, a merchant of Genoa, who had "been at Roccho, diſcovered the matrix of "alum in the iſland of Iſchia, about the year "1459, and eſtabliſhed a manufactory there; "at the ſame time John de Caſtro, who had "viſited the manufactories at Conſtantinople, "diſcovered a matrix at Tolfa, by means of "the ilex aquifolium, which he had alſo ob-"ſerved to grow in the adjacent mountains of "Turkey, and his opinion was confirmed by "the taſte of the ſtones. The attempts made "by the Genoeſe at Viterbium and at Vola-

" terre ſucceeded extremely well; the prepara-
" tion of it in Italy ſoon increaſed wonderfully
" faſt, &c. The firſt manufactory (of alum)
" in England was eſtabliſhed in the reign of
" Elizabeth at Giſborough, by one Thomas
" Chaloner."

It is now very difficult to aſcertain the particular adjective colouring matters, in the fixing of which, alum was uſed among the antients, by reaſon of the imperfect deſcriptions and means employed by them to characteriſe and diſtinguiſh the different objects of natural hiſtory. Some ſpecies of madder however (and perhaps of galium) were undoubtedly uſed by the people of Hindoſtan, Perſia, and Egypt, as well as by the Greeks and Romans; and the kermes inſect was alſo employed by the latter for dying reds. I do not find any account of the particular means by which yellows were dyed among the antients; but there muſt have been many vegetables in all countries capable of producing that colour with alum.

Of ſubſtantive colours uſed by the Greeks and Romans, the moſt conſiderable was the famous Tyrian purple, ſuppoſed to have been firſt diſcovered by the Phenicians, and of which a very full account is given in the fourth chapter of this Work.

But whatever knowledge the Greeks and Romans had derived from others, or acquired by their own obſervations, appears to have been in a great degree loſt about the fifth century; when, as M. Berthollet has obſerved, ſcarce any

any traces of ſcience, induſtry, or humanity were left in what was then called the Weſtern Empire; a little however did remain, and it was afterwards preſerved in Italy, where the Venetians contrived to import many oriental productions and manufactures, which, by affording new means, as well as new objects of imitation, contributed greatly to revive the arts.

According to M. Berthollet, the firſt collection of proceſſes uſed in dying was publiſhed at Venice in 1429, under the name of *Mariegola del' Arte dé Tintori*, of which another edition much improved appeared in 1510; and from this an individual named Giovanne Ventura Roſetti, who travelled into different parts of Italy and the neighbouring countries, to learn the methods and means employed in dying, compoſed, and in 1548 publiſhed a work under the title of Plictho del'Arte de i Tintori, &c. which has been ſuppoſed to have contributed more than any other to the improvements afterwards made in that art. In this work however there is no mention of either indigo or cochineal, which M. Berthollet therefore concludes were not at that time employed by the Italian dyers. This appears to have been the work which, at a meeting of the Royal Society on the 30th of April 1662, Mr. Haak was deſired to tranſlate into the Engliſh language (ſee Dr. Birch's Hiſtory). That learned body had, upon its firſt inſtitution, beſtowed ſome attention to the ſubject of dying, and on the ſame day Sir William Petty, one of its earlieſt and moſt active members, in conſequence of a previous requeſt from the Society, brought in "An Apparatus to the Hiſtory of the Common Practices of Dying," which was afterwards printed in Dr. Spratt's Hiſtory of the Royal Society, and ſeems to have been the firſt account publiſhed in the Engliſh language of the means and operations uſed by dyers. Nearly two years afterwards, *viz.* March 30, 1664, Mr. Boyle preſented to the Royal Society his "Experiments and Conſiderations touching Colours;" and, on the 10th of Auguſt following, it was ordered by the Society "that the way of *fixing colours* ſhould be recommended to Mr. Howard, Mr. Boyle, and Dr. Merrit." Theſe, and eſpecially the two firſt, were among the moſt diſtinguiſhed members of the Society; but it does not appear that they were able to do any thing deſerving of notice, in conſequence of this recommendation. However, at a meeting of the Society on the 11th November 1669, that very ingenious and uſeful member, "Mr. Hooke, produced a piece "of callico ſtained after the way contrived by "himſelf, which he was deſired to proſecute in "other colours beſides thoſe that appeared in "this piece" (Birch's Hiſt. of the Royal Society, vol. ii. p. 401.): And accordingly, on the 9th of the following month, "Mr. Hooke "produced another ſpecimen of ſtaining with "yellow, red, green, blue, and purple colours, "which he ſaid would endure waſhing with "warm water and ſoap." But from this time it does not appear that any thing conſiderable was done, for nearly the ſpace of a century, by men of ſcience in this kingdom, towards improving the arts of dying and callico printing; they being probably diſcouraged by the difficulties which, from the very imperfect ſtate of chymical ſcience, muſt have occurred in every attempt to improve upon what the dyers were able to perform without any principle or theory.

In France however the miniſter Colbert, anxious to extend the commerce and manufactures of that country, turned his attention particularly to the art of dying, with a view to amend as well as to obviate frauds in the practice; and for theſe purpoſes, an "Inſtruction générale "pour la Teinture des Laines & Manufactures "de Laine de toutes Nuances, et pour la "Culture des Drogues ou Ingrédients qu'on "emploie," was prepared under his immediate direction, and publiſhed in 1672. This however was not intended merely to inform, but as a legiſlative act to control the dyers in their operations. It divided them into two claſſes; the one, dyers "*en grand*," were confined to the colours deemed laſting, while the dyers "*en* "*petit teint*" were allowed only to give thoſe which were conſidered as fugitive: and the drugs to be employed in each branch were alſo particularly ſpecified; and the dyers in each prohibited from uſing or having in their poſſeſſion any of the drugs allotted to the other. Reſtraints of this kind, though intended to prevent frauds, muſt have operated as checks upon future improvements, if the government had not encouraged uſeful diſcoveries in this art, firſt by offering particular rewards, and afterwards by appointing thoſe eminent chymiſts, Dufay, Hellot, Macquer, and Berthollet, in ſucceſſion, to ſuperintend and improve the arts connected with chymiſtry, and more eſpecially that of dying.

By Dufay's aſſiſtance M. Colbert's "Inſtruc-"tion" was amended, or rather ſuperſeded by a new one, publiſhed under the adminiſtration of M. d'Orry in 1737. He (Dufay) appears to have been the firſt who entertained juſt conceptions of one of the cauſes of the adheſion of colouring matters to ſtuffs when dyed; I mean that which depends on an affinity or attraction ſubſiſting between ſuch matters and the fibres or ſubſtances of the dyed ſtuffs. He clearly perceived that, without this, cloth while in the dying veſſel could only acquire a degree of colour equal to that of the dying liquor, by an equal participation of the colouring matter diſſolved therein; whereas in fact the cloth is often ſeen to exhauſt, by attracting to itſelf, all the tingent particles of the dying liquor, ſo as to leave it as colourleſs as water. He alſo noticed the difference in the degree of attraction, which different ſubſtances, as wool and cotton, exert upon the ſame colouring matters; and which he found ſo great, that a ſkain of each having been in an equal degree ſubjected to the means and operations commonly employed for dying ſcarlet, the woollen yarn was found to be fully and permanently dyed of that colour, while the cotton retained all its former whiteneſs *. He appears however to have had no conception of the other and more important cauſe of the permanency of adjective colours, I mean that which ariſes from the interpoſition of a ſuitable baſis poſſeſſing a particular attraction both for the coulouring matter and for the dyed ſubſtance, and thereby

* Obſervations Phyſiques ſur le Mélagne de quelques Couleurs dans la Teinture, Mémoires de l'Académie R^e^. &c. 1737.

acting

acting as a *bond of union betweeu them:* nor did his successor Hellot ever approach nearer to the truth on this subject. He, (Hellot,) indeed, published an excellent practical treatise on the art of dying wool and woollen cloths, in which the several processes were accurately described: but in reasoning upon the facts stated therein, he adopted, and suffered himself to be grossly misled by, a frivolous hypothesis, devoid of the least foundation in truth. He fancied that he could discover, in every dying process, some means by which sulphate of pot-ash (then called vitriolated tartar) might be formed; and this neutral salt not being readily soluble by cold water, nor by air or light, he conceived the whole art of dying to consist in first dilating the pores of the substance to be dyed, so as to procure a copious admission of colouring matter, divided by a suitable preparation into atoms, and then wedging or fastening these atoms within the pores of the dyed substance, by the small particles or crystals of this difficultly soluble neutral salt. Upon this *mechanical* hypothesis, he supposed that alum became useful in dying, not by the pure clay or alumine which it contains, and which alone contributes to fix any colouring matter, but by furnishing (and only by furnishing) sulphuric or vitriolic acid, to assist in forming the sulphate of pot-ash, which was to perform this important function of wedging or fastening the colouring atoms; though if he had brought this visionary hypothesis to the test of experiment, as might have been easily done, he would have found not only that no sulphate of pot-ash existed in many cases where he supposed it to produce such important effects, but also that,

even

even if intentionally formed and employed for this purpofe, it poffeffed no power whatever of fixing any colouring matter yet known. But though nothing could be more groundlefs than this theory, the learned in all countries appear to have been fatisfied with it for a confiderable length of time, it being always lefs troublefome to believe than to make experiments. The late celebrated Macquer in a Memoir, printed among thofe of the Royal Academy of Sciences for 1749, mentioning Hellot and his hypothefis, fays, "ce "favant chymifte eft le premier qui ait porté "le flambeau de la phyfique dans l'art obfcur "de la teinture, & qui ait raffemblé et mis en "ordre, fuivant les principles d'une théorie in-"genieufe, les phénomenes et les opérations "bizarres de cet art: il a mis les chymiftes à "portée de voir clair dans ce cahos ténébreux." And afterwards, in the preface to an excellent *Practical* Treatife on Dying Silk, publifhed in 1763, he makes this obfervation, "ce fcroit ici le lieu "d'expliquer la maniere dont les mordants agif-"fent dans la teinture, et de développer la caufe "du bon et du faux teint; mais ces objets out été "traités avec tant de fagacité par M. Hellot, que "je crois devoir y renvoyer le lecteur;" and even fo lately as the year 1766, in an eulogium pronounced upon Hellot in the Royal Academy of Sciences after his deceafe, and publifhed with the mémoires for that year; the fecretary, after explaining Hellot's hypothefis, fays, "à l'aide de "cette théorie fi lumineufe, on ne fera plus "trompé dans la pratique de cet art, que lors "qu'on voudra bien l'être."

Mr. Henry of Manchefter has truly obferved, that "Mr. Keir, the ingenious tranflator of

"Macquer's

"Macquer's Chymical Dictionary, appears to "have been the firſt who ſuſpected that (in "dying) the earth of alum was precipitated, and "in this form attached to the material prepared "or dyed;" and this idea, having been publiſhed, was adopted by Mr. Macquer, and farther extended in the laſt edition of his "Dictionnaire de Chymie," at the article "Teinture," where he ſeems to have formed juſt conceptions of the nature and uſes of alum, and of different metallic ſolutions, as mordants, in dying. This edition was publiſhed in the year 1778, and Mr. Macquer ſoon after announced a deſign of writing a general treatiſe on the art of dying, which his death however fruſtrated. Some time after M. Macquer's deceaſe, the ingenious Mr. Henry of Mancheſter favoured the public with a very intereſting paper, (in the 3d volume of the Memoirs of the Mancheſter Society,) "On the "Nature of Wool, Silk, and Cotton, as Objects "of the Art of Dying; on the various Prepa-"rations and Mordants requiſite for theſe dif-"ferent Subſtances; and on the Nature and "Properties of Colouring Matter, &c." a paper replete with uſeful information and ingenious ideas, (particularly reſpecting the cauſes of the durability of what is called the Turkey red,) and which deſervedly reflects great credit on the author's talents and acquirements. And in the year 1791, that moſt excellent chymiſt M. Berthollet, who had been appointed by the government of France to ſucceed M. Macquer in ſuperintending the arts connected with chymiſtry, and particularly dying, publiſhed a work of great merit, under the title of "Elémens de l'Art de la Teinture," in two volumes, which has ſince been tranſlated into Engliſh by Dr. Hamilton.

Before

Before the publication of Mr. Berthollet's work, I had collected moſt of the materials for this undertaking; and, though he has anticipated many things which I was prepared to mention, (ſome of which I ſhall notwithſtanding mention in my own way,) this production afforded me great pleaſure as well as profit; becauſe the author's ſuperior chymical knowledge has enabled him to take juſt views of many intricate parts of his ſubject, and to reaſon with ſolidity, as well as ſagacity, upon the operations of dying in general, probably without having had leiſure to do much *experimentally* towards their improvement. He has moreover enabled me to abridge my own work, by referring to his, for more ample information upon ſeveral topics, particularly thoſe of fuel, the different acids, alum, the ſulphates of iron, copper, and zinc, verdigriſe, acetite of lead, the different alkalies, ſoap, ſulphur, arſenic and water, of all which he has treated ſo ably and fully as to leave but very little for me to add reſpecting any of them.

But though I have been preceded by authors of ſuch diſtinguiſhed ability as Mr. Henry and M. Berthollet, the new facts and obſervations which I have to offer my readers will ſhew that I did not find the ſubject exhauſted: And indeed it is ſo far inexhauſtible that it probably will afford ample employment for the greateſt talents and induſtry during many generations.

In juſtice to that very reſpectable chymiſt Mr. Chaptal, I ought to mention that his excellent work intituled, "Elemens de Chimie," and publiſhed

publiſhed in the year 1790, (in three volumes,) contains many ingenious facts and obſervations relating to the cauſes of the production and changes of colours, as well as to ſeveral other ſubjects connected with dying. Some other works deſerving of notice have alſo within a few years been publiſhed on this ſubject, particularly that of Scheffer with notes by the celebrated Bergmann; another by Pœrner, which has been tranſlated into French from the German, and publiſhed with notes by Deſmarets and Berthollet; and a third by Dambourney; but neither of theſe has done much towards improving the theory of dying. That of Pœrner contains an account of many experiments made by the author with different dying drugs; but unfortunately his reaſonings upon them, and upon every part of the ſubject, are highly defective. Dambourney (a reſpectable merchant) was poſſeſſed of no chymical ſcience, and he has done little more than give an account of the trials which he made with a conſiderable number of vegetable matters; few of which are likely to be ever much, if in any degree, employed by dyers.

Of the introduction of callico printing into Europe, and its progreſs, my readers will find an account in the ſeventh chapter of this volume.

Eminent Writers have derived the arts of dying and callico printing from a conſiderable degree of perfection, which they ſuppoſe chymiſtry to have ſomewhere attained in remote ages, though afterwards loſt; and they imagine that particular proceſſes of the art were preſerved

after

after the principles on which it was founded had been forgotten *: I am not able however to perceive any sufficient ground for these opinions. In fact, there is no good reason to believe, that chymistry ever had made any such progress among the antients, or that they ever were so much engaged in the pursuit of knowledge by *experiment*, as would have been necessary for the acquisition of but a moderate portion of chymical science †. Even the operations of callico printing, as practised by the people of India, and which above all others have been considered as the result of an improved state of chymistry, are in many respects highly inconvenient, and incumbered with useless parts which a little chymical knowledge would have taught them to reject, as indeed they were rejected by the people of Europe very soon after callico printing began to be practised here, though it began and was continued for some time with little or no aid from chymical science. And considering how far many of the operations of dying and callico printing have been carried towards perfection, unassisted by principles, we may say of this art, or until very lately might have said what Lord Bacon says of music, that "the practice has been well pursued and in good variety, but the theory weakly; especially as to assigning the causes of the practice." Bacon's Works, by Mallet, vol. III. p. 29.

* See Mr. Henry's paper in the third volume of the Memoirs of the Manchester Society. Also Hist. & Memoires de l'Acad. R. des Sciences, &c. 1750, and 1766.

† Pliny observes, that dying had never been considered as a liberal art; and he alleges this, as an excuse for not giving a *rationale* of it. Lib. xxii. § 3. But it was a mere excuse, because no degree of science then in the world could have enabled him to do so.

But

But notwithſtanding the obſervations of many individuals occupied with the means and operations of dying, through a long ſucceſſion of ages in different countries, joined to very important *accidental* diſcoveries occurring from time to time, have produced great improvements in this art, with but little help from theory, we are not to infer that a knowledge of its true principles, and of the cauſes which operate in producing its various effects, will not prove uſeful in the higheſt degree: for "though (as Mr. "Henry has well obſerved) long experience "may eſtabliſh a number of facts, yet, if the "rationale of the manner by which they are "produced be not underſtood, miſapplications "are liable to be made; ſimilar practices are "purſued where the caſes differ eſſentially; and "improvements are attempted at hazard, and "often on falſe principles." And in confirmation of theſe truths, perhaps I cannot better conclude this Introduction, than by adding the following quotation from the Hiſtory and Memoirs of the Royal Academy of Sciences at Paris, for the year 1761, *viz.*

"*La deſcription des arts, faite avec une* "*exactitude celairée, deponillée de toutes les* "*pratiques inutiles que l'ignorancé tousjours* "*myſterieuſe y accumule ſans ceſſe, & reduite* "aux principes conſtans de la ſaine theorie, *eſt* "*peutetre le moyen le plus propre a hater leur* "*perfection, et a rendre plus abondantes* ces "ſources de biens & de commodités, que "l'etre ſupreme a voulu que les hommes "duſſent a leur travail, et a leur induſtrie."

Expe-

# Experimental Researches

CONCERNING THE PHILOSOPHY OF

# PERMANENT COLOURS,

AND THE

# Beſt Means of producing them, by DYING, CALLICO PRINTING, &c.

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## CHAP. I.

### *Of the permanent Colours of Natural Bodies.*

" Ceux qui exigent qu'on leur donne la raiſon
" d'un *effet general*, ne connoiſſent, ni l'etendue
" de la nature, ni les limites de l'eſprit humain."
M. DE BUFFON.

THE ſubject of this chapter was covered with almoſt total darkneſs, until the immortal Newton threw light upon it, by *diſſecting*, if I may ſo expreſs myſelf, the *matter* of *light* itſelf. By his Experiments we have been taught, that " the light of the ſun conſiſts of rays differently *refrangible*;" and that, when ſeparated by the priſm, in conſequence of their different degrees of refrangibility, they afford all the various ſhades of colour, running gradually into each other, according to their particular degrees of refrangibility; the violet being moſt refracted; the indigo next; then the blue, green, yellow, orange, and red, which, of all others, is the leaſt refracted; that the ſame rays alſo differ in degrees of reflexibility, according to their degrees of refrangibility.

That the proper colour of homogeneal light, depending on its particular degrees of refrangibility, cannot be changed by reflections or refractions; and "if the ſun's light conſiſted of but one ſort of rays, there would be but one colour in the whole world," nor the poſſibility of producing any new colour by reflections and refractions; and therefore, "that the variety of colours depends upon the compoſition of light."

That "colours, *in an object*, are nothing but a diſpoſition to reflect this or that ſort of rays, more copiouſly than the reſt; *in the rays*, they are nothing but their diſpoſitions to propagate this or that motion into the ſenſorium; and *in the ſenſorium*, they are ſenſations of thoſe motions, under the *forms of colours*."

That "colours may be produced by compoſition, which ſhall be like to the colours of homogeneal light as to the *appearance of colour*, but not as to the immutability of colour and conſtitution of light; and thoſe colours, by how much they are more compounded, by ſo much are they leſs full and intenſe; and by too much compoſition they may be diluted and weakened, till they ceaſe, and the mixture becomes grey. There may be alſo colours produced by compoſition, which are not fully like any of the colours of homogeneal light." "For a mixture

of

of homogeneal red and yellow compounds an orange, like, in appearance of colour, to that orange which, in the ſeries of unmixed priſmatic colours, lies between them; but the light of one orange is homogeneal as to the refrangibility, and that of the other is heterogeneal; and the colour of the one, if viewed through a priſm, remains unchanged; that of the other is changed, and reſolved into its component colours, red and yellow. And after the ſame manner other neighbouring homogeneal colours may compound new colours, &c." And if to a colour ſo compounded other colours be added in ſufficient quantities, they will gradually overcome the firſt, and produce "whiteneſs, or ſome other colour." "So if to the colour of any homogeneal light, the ſun's white light, compoſed of all ſorts of rays, be added, that colour will not vaniſh or change its ſpecies, but be diluted; and by adding more and more white, it will be diluted more and more perpetually." "Laſtly, if red and violet be mingled, there will be generated, according to their various proportions, various purples, ſuch as are not like, in appearance, to the colour of any homogeneal light; and of theſe purples, mixed with yellow and blue, may be made other new colours." "That whiteneſs, and all grey colours between white and black, may be compounded of colours, and the whiteneſs of the ſun's light, is compounded of all the primary colours mixed in due proportion." To illuſtrate this, he produced *whiteneſs*, firſt by a mixture of the priſmatic colours, and then by mixtures of differently coloured ſubſtances, in due proportions.

Each particular colour being therefore a property of that particular ſort of ray which produces the perception thereof, Sir Iſaac Newton concludes, that the permanent colours of natural bodies ariſe from hence, that ſome of them "reflect ſome ſorts of rays, others other ſorts, more copiouſly than the reſt." "Minium reflects the leaſt refrangible, or red making rays moſt copiouſly, and thence appears red. Violets reflect the moſt refrangible moſt copiouſly, and thence have their colour, and ſo of other bodies;" and "whilſt bodies become coloured, by reflecting or tranſmitting this or that ſort of rays more copiouſly than the reſt, it is to be conceived that they ſtop and ſtifle in themſelves the rays which they do not reflect."

Sir Iſaac Newton's demonſtrations and illuſtrations of this doctrine may be ſeen at large in the *firſt* Book of his Optics, to which I beg leave to refer, without preſuming to offer the ſmalleſt objection thereto. The celebrated Euler has, indeed, conceived light to be propagated like ſound, by a vibrating motion, and that the different degrees of velocity, or frequency with which theſe motions or vibrations ſucceſſively reach the organs of viſion, occaſion the ſenſations or perceptions of the different colours, as thoſe of air occaſion the differences of ſound, and that colours are to the ſight, what ſounds are to the organs of hearing. But this analogy, though it may ſerve to illuſtrate, will not prove the truth of his opinion; and as he does not offer any other ſatisfactory proof of it, or any means to overcome the difficulties with which it is attended, I ſhall thus far adhere to Sir Iſaac Newton's ton's doctrine. His *second* Book, however, appears to contain matter which is liable to considerable objection. He begins it with "Observations concerning the reflections, refractions, and colours of thin transparent bodies;" and mentions what had been observed by others, "that transparent substances, as glass, water, air, &c. when made very thin by being blown into bubbles, or otherwise formed into plates, do exhibit various colours, according to their various thinness; although at a greater thickness they appear very clear and colourless." And though he considers these colours as "of *a more difficult consideration*," yet as "they may conduce to farther discoveries for completing the theory of light, *especially as to the constitution of the parts of natural bodies, on which their colours or transparency depend*," he delivers his own observations on this subject: Of these, the principal was made, by taking "two object glasses, the one a planoconvex, for a fourteen foot telescope, and the other a large double convex, for one of about fifty foot; and upon this, laying the other with its plane side downwards, I pressed them slowly together, says he, to make the colours successively emerge in the middle of the circles, and then slowly lifted the upper glass from the lower, to make them successively vanish again in the same place. The colour which, by pressing the glasses together, emerged last, in the middle of the other colours would, upon its first appearance, look like a circle of a colour, almost uniform from the circumference to the center; and by compressing the glasses still more, grow continually broader, until a new colour emerged in its center, and thereby it became a ring, encompaſſing that new colour; and by compreſſing the glaſſes ſtill more, the diameter of this ring would increaſe, and the breadth of its orbit, or perimeter, decreaſe, until another new colour emerged in the center of the laſt; and ſo on, until a third, a fourth, a fifth, and other following new colours ſucceſſively emerged there, and became rings, encompaſſing the innermoſt colour; the laſt of which was the black ſpot: And on the contrary, by lifting up the upper glaſs from the lower, the diameter of the rings would decreaſe, and the breadth of their orbit increaſe, until their colours reached ſucceſſively to the center; and then they being of a conſiderable breadth, I could more eaſily diſcern and diſtinguiſh their ſpecies than before." And theſe he found to be in ſucceſſion from the black central ſpot as follows, viz. firſt, blue, white, yellow, and red; then in the next circuit or order immediately encompaſſing theſe, were violet, blue, green, yellow, and red; in the third circuit or order were purple, blue, green, yellow, and red; after this ſucceeded in the fourth circuit green and red; then the fifth of greeniſh blue and red; next, the ſixth, of greeniſh blue and pale red; and laſtly, the ſeventh, of greeniſh blue and reddiſh white: but the colours in the laſt three circuits he deſcribes as having been very indiſtinct, and ending in perfect whiteneſs.

" By looking through the two object glaſſes," continues he, " I found that the interjacent air exhibited rings of colours, as well by tranſmitting light, as by reflecting it. The central ſpot was now *white,* and from it the orders of the colours

colours were yellowiſh red; black, violet, blue, white, yellow red; violet, blue, green, yellow, red, &c. But theſe colours were very faint and dilute, unleſs when the light was trajected very obliquely through the glaſſes. Comparing the coloured rings made by reflexion, with thoſe made by the tranſmiſſion of light, I found," adds he, "that white was oppoſite to black, red to blue, yellow to violet, &c." And as rings of ſimilar colours were obſerved in bubbles, "blown with water, firſt made tenacious by diſſolving a little ſoap in it," Sir Iſaac Newton endeavoured mathematically to aſcertain the different comparative thickneſſes of air, water, and glaſs, at which the ſeveral circuits or orders of colours appeared as before mentioned, which he has noted in a table prepared for that purpoſe, and from which this remarkable fact appears, that *ſimilar colours* in the different orders *occur, and are repeated over and over again at very great diverſities of thickneſs*; a circumſtance which, in my humble opinion, *proves inconteſtibly*, that though *thickneſs* might *be one*, it *could not be*, as *he ſuppoſes, the only cauſe of theſe repeated variations of colour*[1]. And, indeed, they are obviouſly to be explained, in the ſame way as the colours of the priſm, the rainbow,

[1] Sir Iſaac Newton ſeems to have foreſeen this objection to his hypotheſis, and to have endeavoured to obviate it, by ſuppoſing the exiſtence of what he denominated different *orders* of colours; in each of which it was conceived that the red, orange, yellow, &c. required for their production very different thickneſſes from thoſe which produced the ſame colours in the other orders: this, however, was but a ſuppoſition, improbable in itſelf, and repugnant to a multitude of facts, which will be mentioned in the courſe of this work.

&c. and ought not to have been employed towards explaining the caufes of *permanent colours* in different fubftances; or the changes which may be produced in them, by various compofitions and decompofitions; thefe being chymical effects, and dependent upon chymical principles. It was, however, at that period, the fafhion to afcribe *even chymical effects* to *mechanical caufes*: alkalies were fuppofed to neutralize acids, as the blade of a fword is fheathed by its fcabbard; and the moft learned phyfician of his age, foon after, thought it proper to write a *Mechanical Account of Poifons*. We are not, therefore, to wonder, that Newton himfelf fhould have been mifled on this fubject, fince the whole amount of chymical knowledge in his time, had he poffeffed it, would, like an *ignis fatuus*, have only ferved to light him aftray; as in truth it feems, in fome degree, to have done; for, after ftating as a propofition, that "the tranfparent parts of bodies, according to their *feveral fizes*, reflect rays of one colour, and tranfmit thofe of another, on the fame grounds that thin plates or bubbles do reflect thofe rays," he goes on to mention, "that, by mixing divers liquors, very odd and remarkable productions, and changes of colours may be effected; of which no caufe can be more obvious and rational, than that the faline corpufcles of one liquor do varioufly act upon, and unite with, the tinging corpufcles of another, *fo as to make them fwell or fhrink* (whereby not only their bulk, but their denfity alfo, may be changed), or to divide them into fmaller corpufcles (whereby a coloured liquor may become tranfparent), or to make many of them affociate into one clufter, whereby two tranfparent liquors may

may compoſe a coloured one:" and laying it down as a propoſition, that "the *bigneſs* of the component parts of natural bodies may be conjectured by their colours," he endeavours, among other things, to explain why the ſyrup of violets, "by acid liquors, turns red, and, by urinous and alkalizate, turns green;" and for this purpoſe, he ſuppoſes, that "it is the nature of acids to diſſolve or attenuate, and of alcalies to precipitate or incraſſate;" a ſuppoſition which, as acids and alcalies are *chymical agents*[2], is not true of either of them, in the ſenſe in which Sir Iſaac Newton appears to have underſtood it; though, in another ſenſe, it is partly true and partly falſe of both; ſince both are capable of diſſolving a great variety of ſubſtances, and when a ſubſtance is diſſolved by either of them, it will moſt commonly be decompoſed and precipitated by the other: but certainly the effect of coagulating, or *incraſſating*, which he aſcribes to alkalies, is much more frequently produced by acids; though nothing like it is produced by either, in any of the changes of colour, which they occaſion to the ſyrup of violets. It muſt be alſo obſerved, that Sir Iſaac Newton has himſelf admitted, that what he calls "fat, ſulphureous, unctuous bodies," poſſeſs refractive powers "two or three times greater, in reſpect of their *denſities*, than the refractive powers of other ſub-

[2] When acids "diſſolve or attenuate," it is by combining and forming a new compound with the matter ſo diſſolved or attenuated; and when alkalies "precipitate or incraſſate," they always produce new compoſitions and decompoſitions; changes which are totally foreign to thoſe mechanical effects by which Sir Iſaac Newton intended to explain the changes of colour in queſtion.

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ſtances in reſpect of their's;" an admiſſion which ſeems incompatible with the concluſion which he almoſt immediately after draws, " that nothing more is requiſite for producing all the colours of natural bodies, than the ſeveral ſizes and denſities of their parts."

In the year 1765, Mr. Edward Huſſey Delaval, F. R. S. communicated ſome " Experiments and Obſervations on the agreement between the ſpecific gravities of the ſeveral metals, and their colours, when united to glaſs, as well as of their other preparations," in a letter to the Earl of Morton, then preſident of the Royal Society: a communication for which the Society beſtowed on him the annual gold medal provided by Sir Godfrey Copley. And though Mr. Delaval. in this communication, " treats of the difference of *denſity* and the *colours* produced by that cauſe," he, notwithſtanding, conſiders theſe as connected with " the colours ariſing from a difference of the ſize of the colouring particles;" ſince, " by ſeparating the particles of a coloured ſubſtance, they are removed to a greater diſtance from each other, ſo as to occupy more ſpace," and, therefore, the ſubſtance ſo affected " muſt undergo *a diminution of its ſpecific gravity, at the ſame* time that the ſize of its particles is leſſened." And as Sir Iſaac Newton had inferred, that the refractive and reflective powers of bodies were nearly proportional to their denſities, and that the leaſt refrangible rays require the greateſt power to reflect them, Mr. Delaval conceived, " that denſer ſubſtances ought, by their greater reflective power, in like circumſtances, to reflect the leſs refrangible rays; and that

that ſubſtances of leſs denſity, ſhould reflect rays proportionably more refrangible, and thereby appear of ſeveral colours, in the order of their denſity." And, in ſupport of this opinion, he undertook to " give inſtances of natural bodies, which differ from each other in denſity, though circumſtanced alike in other reſpects;" and alſo differ " in colour in the ſame order as they do in denſity; the denſeſt being red, the next in denſity orange, yellow, &c."

" In ſuch an inquiry," ſays he, " metallic bodies ſeem to demand our firſt and principal attention, as their ſpecific gravities have been aſcertained by well-known and repeated experiments." Mr. Delaval, however, muſt doubtleſs have perceived, that metals, in their pure ſimple forms, could not ſuit his purpoſe of ſupporting and extending the doctrine of Sir Iſaac Newton in this reſpect; ſince platina, which is much the heavieſt of all metals, and of all known ſubſtances, inſtead of being the *moſt red*, as upon this hypotheſis it ought to have been, is white, like tin, the lighteſt of metals; and gold, the heavieſt of metals after platina, is much farther removed from the red colour than copper, which is ſo much lighter. And this is alſo the caſe of quickſilver, lead, &c. To obviate ſo formidable a difficulty, he thought it expedient to premiſe, that, " as the inflammable matter in the intire metals, acts ſtrongly on the rays of light, it is neceſſary to calcine, or divide them into extremely minute particles, in order to examine ſeparately the action of the calx, or *fixed* matter, on the rays of light." But here, at the very threſhold, Mr. Delaval is forced

forced to ſuppoſe the preſence of what he calls inflammable matter, *acting ſtrongly on the rays of light*, and thus producing or changing colours, by properties very different from thoſe of denſity, and ſize or thickneſs of particles. I might here deny, as, in truth, I am very far from believing, the exiſtence of any ſuch matter in metals, which, according to the new and prevailing chymical doctrine, are ſimple ſubſtances, uncombined with any thing like what is here ſuppoſed. Admitting however, for the ſake of argument, that phlogiſton, or inflammable matter, does exiſt in metals; it muſt be recollected, that their calcination is not a mere abſtraction thereof, ſince there is no fact in chymiſtry better aſcertained, or more univerſally admitted, than that every metal in its calcination unites, with a conſiderable portion of vital air, or its baſis, the oxygene[3] of the modern chymiſts, and which (only by variations in the proportions) is capable of producing, with particular

[3] By oxygene is meant that ſubſtance which, combined with and rendered elaſtic by heat, or by heat and light, conſtitutes vital air; or what Dr. Prieſtley terms dephlogiſticated air (firſt diſcovered by him in Auguſt 1774), the only fluid ſuited for reſpiration; the *pabulum vitæ*, without which the more perfect animals cannot live, even for a few minutes. But as the ſtimulant or exhilarating effects of this (vital) air would excite, and wear out, the powers of life too much and too rapidly, if it were inſpired without mixture, the wiſe Author of Nature has preſented it to us diluted with about three times as much of a different air not reſpirable by itſelf, and which, from that circumſtance, is now denominated *azote*. Theſe two airs, with a very ſmall portion of carbonic acid gas, or fixed air, and ſome few accidental or extraneous matters, compoſe our common atmoſpheric air. The oxygene, combined with the azote, conſtitutes, according to their different proportions, either the

cular metals (and with other ſubſtances), all the poſſible variations of colour. Of this however Mr. Delaval takes no account: indeed, when treating of the colours of Mercury, he expreſsly ſays, "I have not entered into the conſideration of the air, which unites with mercurial colours during their expoſure to fire; becauſe it does not relate to *the greater or leſs diviſion of their particles*, which is the immediate ſubject of my inquiry." So that, by his own ſtatement, he has overlooked (becauſe it did not ſuit his hypotheſis) the only thing worthy of notice on this ſubject; ſince the oxyds or calces of Mercury indiſputably receive a variety of colours from nothing but additions, greater or ſmaller, of that air which he profeſſes to have diſregarded; and which having, as he declares, no relation to the greater or leſs diviſion of their particles, evidently proves, that the various colours aſſumed by theſe calces, under the circumſtances in queſtion, do not reſult from any ſuch diviſion of their particles.

But though Mr. Delaval inculcates the neceſſity of calcining metals, "in order to examine ſeparately the action of their oxyds, or fixed matter, on the rays of light," he does not

the nitrous or nitric acid; the ſame oxygene united to ſulphur by combuſtion, produces either ſulphureous or ſulphuric (vitriolic) acid; and, with other baſes, it ſeems to produce moſt, if not all, of the other acids. With pure charcoal (carbone) it produces carbonic acid (or fixed air), and with inflammable air (hydrogene) it ſeems now certain that it produces water. This explanation may be uſeful to ſuch readers as do not happen to be acquainted with the more modern chymiſtry.

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adduce the colours which they aſſume when ſo calcined, as any evidence of the truth of his hypotheſis; and indeed he muſt have perceived them to be abſolutely incompatible with it, ſince the ſame oxyd, by different degrees of calcination, exhibits very great diverſities of colour. And therefore that he might obtain from ſeveral of the metals ſuch colours as ſuited his purpoſe, he continued to melt them with what he was pleaſed to think "a proper quantity of the pureſt glaſs," and as they, when more or leſs calcined, and melted or united with a greater or leſs portion of glaſs, are capable each of giving ſeveral, and ſome of giving all the colours, it could not be difficult for him to find out, and aſſign to each metal, as its proper colour, that which it ought to have, upon his ſuppoſition that the colours of metals depended on their reſpective denſities. Thus, for example, iron highly calcined, or combined with a large portion of the baſis of vital air, (oxygene,) gives a red colour to melted glaſs; and if the glaſs be continued in fuſion, the oxygene will by degrees be ſeparated, and in proportion to its ſeparation, the colour of the glaſs will change to orange, yellow, green, blue, and white. And as blue is the colour which ſuits Mr. Delaval's purpoſe, he ſelects and aſſigns it as the proper colour of iron, and the degree of heat producing it, as the proper one for manifeſting the true colours of metals; though in fact he took no means to aſcertain what this degree of heat really was; and the effect, or blue colour, would require very different degrees, according to the greater or leſs degree of calcination which the calx of iron had previouſly undergone, or, in other words, according to the quantity of oxygene combined with it.

Where every thing is in this way aſſumed or ſuppoſed at pleaſure, not only without evidence or probability, but often againſt both, it muſt have been eaſy for Mr. Delaval to prop up an hypotheſis which has no foundation in truth. I have now before me a pile of facts and obſervations reſpecting the almoſt infinite variety of colours which different metals aſſume in different ſtates and circumſtances, and which I had arranged for the purpoſe of ſhewing more particularly the fallacy of every thing alleged on this ſubject by Mr. Delaval; but I am conſtrained to lay them aſide, from a conviction, that if I were now to employ them for this purpoſe, there are few, if any, who would have patience enough to read a ſtatement of them.

Mr. Delaval has quoted, from Glauber's Proſperity of Germany (tranſlated by Packe, 1689), ſome curious obſervations reſpecting the great and ſurpriſing variety of colours produced by manganeſe; and he adds, as from his own knowledge, that "amongſt the mineral ſubſtances none affords a greater variety of bright colours, eſpecially when it is fuſed with nitre, or a fixed alkali:" of theſe he inſtances a yellow, produced by diſſolving manganeſe in a weak ſpirit, together with a green, blue, purple, and red, produced by water poured on it; in the firſt inſtance cold, and in the others warm, then warmer, hot, and boiling; all which colours he aſcribes to different degrees of ſolution,

or

or attenuation, of the particles of manganeſe. But in truth this and other metallic calces or oxyds, had he properly attended to their various changes of colour, might have ſhewn him both the fallacy of his own hypotheſis, and the road to a better. Manganeſe is the oxyd or calx of a metal which has ſo ſtrong an attraction for the baſis of vital air, that one of the moſt excellent of all chymiſts, Berthollet, ſays, we may ſafely conſider the whole of what exiſts in nature to be as in a ſtate of oxydation, or combination with oxygene: when ſaturated therewith, I mean with the baſis of vital air, it is black; and if it be diluted or diffuſed in melted glaſs, it becomes purple, or red; and as the vital air diminiſhes by burning, with the coaly impurities (which it is uſed for deſtroying) in glaſs, it gradually loſes its power of producing colours, and leaves the glaſs tranſparent and colourleſs; its colours, however, may be reſtored by nitre, or any thing affording pure air. The different ſolutions of manganeſe, mentioned by Glauber, Mr. Delaval, and many others, undergo their various changes of colour, in conſequence of a gradual ſeparation or diminution of their oxygene: and that this is what manganeſe poſſeſſes, and what it loſes, in theſe operations, muſt be evident to all who are acquainted with the later chymical diſcoveries, and the very extraordinary purpoſes to which Mr. Barthollet and others have found it applicable (particularly thoſe of bleaching, and the manufacture of a new and moſt powerful kind of gun-powder); and which it effectuates ſolely by the pure or vital air obtained from it. I have already noticed the various colours aſſumed by the oxyds or calces of iron,

iron, when combined with different portions of the ſame air, or its baſis, the oxygene, which are indeed ſo many and ſo diverſified, that I remember having been told by Mr. Wedgwood, not long ſince, that all the fine diverſified colours applied to his pottery, were produced only by the oxyds of this ſingle metal; which muſt have been all of the ſame, or very nearly the ſame, ſpecific gravity, and were beſides, in theſe caſes, combined or melted with glaſs, the ſubſtance which Mr. Delaval himſelf thought proper to chooſe, as being of all others the beſt for exhibiting what he was pleaſed to think the true colours of metals. In like manner the oxyds or calces of mercury, lead, ſilver, biſmuth, antimony, &c. aſſume each a conſiderable variety of colours (and more eſpecially the two firſt), by combinations with different portions of oxygene, without any thing like a correſpondent variation of denſity or ſpecific gravity in any of them. Of this Mr. Delaval appears to have been ſenſible; and in the inſtance of lead, he endeavours to obviate the evidence which it affords againſt his theory, by aſcribing the various colours of that metal to its "imperfection," which he is pleaſed to *ſuppoſe*, without any, and againſt every, kind of proof and probability: and then he goes on to ſay, "it is probable that, during the calcination, lead receives a ſmall portion of *phlogiſton* as well as of air; for the affinity between the earth of this metal and inflammable matter is very great, as appears from the readineſs with which its ſolutions and calces unite with phlogiſtic vapours. The effect of ſuch an union," adds he, "muſt probably be a change of colour from orange to red; for Sir Iſaac Newton has

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ſhewn, that bodies reflect more ſtrongly in proportion as they poſſeſs more phlogiſton, and that the leſs refrangible colours require greater power to reflect them." Here we have another gratuitous and ſtrange ſuppoſition of an acceſſion or combination of phlogiſton with lead in calcination: I ſay ſtrange, becauſe thoſe of the adherents of phlogiſton who yet continue to believe its exiſtence in metals, have conſtantly ſuppoſed that, in calcination, while they received air, they *loſt*, *inſtead of gaining*, *inflammable matter*. But were this extravagant ſuppoſition to be admitted as a cauſe of the changes of colour in metals, how can it be reconciled to any hypotheſis which makes their colours depend on their reſpective denſities? Indeed, if the effects which Sir Iſaac Newton ſuppoſes phlogiſton to have on colours were real, and if phlogiſton really exiſted in them, as both he and Mr. Delaval, as well as others, have until lately imagined, it would be difficult to conceive why all metals are not red, or more inclined to redneſs, than their calces or oxyds. But enough, perhaps too much, has been ſaid, to refute Mr. Delaval's hypotheſis, ſo far as it relates to the colours of metals. Unfortunately, however, for my readers, as well as for myſelf, he has thought proper, in a larger work [4], publiſhed ſome time ſince, to extend the ſame hypotheſis to the colours of animal and vegetable ſubſtances; and endeavour to confirm and illuſtrate Sir Iſaac Newton's ideas on this ſubject, by a variety of experiments, which are repreſented as inſtances of changes of colour produced in theſe ſubſtances, by an increaſe or diminution in the

[4] Experimental Enquiry into the Cauſe of the permanent Colours of opake Bodies. 4to.

ſizes,

ſizes of their particles: I am, therefore, compelled reluctantly to extend my own obſervations a little farther on this matter; and I muſt begin by complaining of a continuance of *gratuitous* and *fallacious ſuppoſitions*, ſimilar to thoſe which I have before had occaſion to notice; for when, in operating upon, or with different matters, he profeſſes either to increaſe or diminiſh the ſizes of their particles, and *to do nothing more*, in order to ſhew that the changes of colour produced in them, accord with the thickneſſes expreſſed by Sir Iſaac Newton, in the table which I have already mentioned; inſtead of chooſing and employing mechanical means, which alone are ſuited to produce thoſe effects, and only thoſe effects, he has recourſe to mere chymical agents, whoſe actions in the ways which he ſuppoſes muſt have been almoſt always doubtful, though their powers of producing other, and very different effects from what he ſuppoſes, is moſt certain. Mr. Delaval, however, adopting Sir Iſaac Newton's ſuppoſition, that acids always attenuate, and alkalies always incraſſate, prepared what he conſidered as a diſſolving or attenuating liquor; which "conſiſted of water, with about an eightieth part of *aqua fortis*:" and when he wanted to leſſen the diſſolving force of this liquor, inſtead of weakening it by the addition of water (which would certainly have been the moſt obvious and unexceptionable expedient), he choſe to do it, as he ſays, by adding "a ſmall quantity of a ſolution of potaſh, or ſome other alkaline liquor;" and thereby produced a new compoſition, the effects of which muſt, in many caſes, prove different from thoſe of a mere diminution of the ſuppoſed diſſolving power of the former liquor. And on the other hand, when he wanted to increaſe the force of his acid liquor, inſtead of doing it by a farther addition of aqua fortis (obviouſly the moſt proper expedient), he recurs to an addition of *oil of vitriol*; an acid poſſeſſing very different properties, and producing very different effects, on a great variety of ſubſtances, and particularly on colouring matters; of which I could eaſily allege hundreds of inſtances, but ſhall content myſelf with only mentioning what is well known, that even the ſtrongeſt and moſt concentrated oil of vitriol (uſed to diſſolve indigo for dying the Saxon blue, &c.) does not deſtroy, or even weaken, its blue colour, though a very weak nitrous acid, or aqua fortis, will wholly deſtroy it, and convert the indigo to a dirty brown maſs, of no uſe whatever.

Having thus aſſumed, that acids attenuate, and do nothing but attenuate, the particles of colouring matter; that alkalies incraſſate, and do nothing but incraſſate, the ſame particles; that by adding an alkali to his mixture of aqua fortis and water, he weakens, and only weakens, its attenuating force on one hand; and that on the other he increaſes, and only increaſes it, by an addition of vitriolic acid; he next provides himſelf with ſo much of Sir Iſaac Newton's table before mentioned as ſuits his purpoſe, by tranſcribing the different colours of the three firſt orders, and the different thickneſſes of air, water, and glaſs, ſuppoſed to produce each of theſe colours, one after the other; and thus equipped, he proceeds to make experiments upon red infuſions of certain vegetables, and generally

generally finds, that with his acid liquor (*i. e.* water with $\frac{1}{80}$ of aqua fortis) the colour continues *red*; that, with the addition of oil of vitriol, to attenuate farther, as he ſuppoſes, it becomes yellow; and that if, inſtead of oil of vitriol, he adds an alkali, to *incraſſate,* it becomes a purple. Now it ſo happens, that though all the other colours are repeated in more than one order, purple is marked but once in Sir Iſaac Newton's table, and then it is placed as the firſt colour of what he terms the third order; and if the red and yellow, from which the purple in queſtion had proceeded, were ſuppoſed to be of the ſame order (as might be expected), then the production of this purple ought, upon Mr. Delaval's theory, to reſult not from incraſſation, but from attenuation; ſince the particles of it are ſtated as near one third leſs in ſize, than the particles of the red, and near one fourth ſmaller than thoſe of the yellow, of the ſame order: but ſuch is the happy arrangement of this table, and of the ſeveral orders of colours, that, by ſuppoſing the red in this inſtance to be the red of the ſecond order, he finds a purple below it in the third, with *only one intervening colour*, and a yellow at *the ſame diſtance above*; and theſe leaps not being very great, he reconciles the appearances to the theory. Indeed, as the ſecond, or middle order in the table, contains all the different colours, and as, excepting one, they are all repeated in the firſt order, which is above; and alſo in the third, which is below; hardly any change of colour can happen, which may not be made to accord with Mr. Delaval's hypotheſis, he being always allowed to ſuppoſe each original or primitive colour to belong to

 that

that order which may be found moſt convenient; though, in truth, the very admiſſion of different orders or repetitions of the ſame colours, produced repeatedly by and at *different* thickneſſes, or ſizes, either of particles or plates of matter, is of itſelf a proof (as I have before obſerved) that ſuch colours do not depend on any particular thickneſs of plates or ſize of particles[5].

I am far from thinking that Mr. Delaval has always choſen the moſt proper matters for fair experiments, or that the experiments themſelves, even on his own principles, were well calculated to aſcertain the truth. But ſuch as they are,

[5] When Mr. Delaval, on every occaſion, allots each particular colour to ſome one order, excluſively of the reſt, it would ſeem reaſonable to expect, that he ſhould juſtify this allotment by ſomething beſides his own convenience, and particularly that he ſhould prove that the red, for inſtance, which he places in the ſecond order, exceeds that of the firſt order, in the denſity and ſize of its particles, exactly in the ſame proportion as $18\frac{1}{3}$ exceeds 9; and that the red which he places in the third order, exceeds that of the ſecond exactly in the proportion of 29 to $18\frac{1}{3}$: and that the other colours of the ſeveral orders differ from each other likewiſe, according to the proportions ſtated as neceſſary for their production in the table which he has adopted from Sir Iſaac Newton. Before this diviſion of colours into orders, and the hypotheſis connected with it, can be admitted to have any other than an imaginary foundation, it ought to be proved, that all the known reds differ from each other in reſpect to the denſities and ſizes of their particles, *exactly according to the before mentioned proportions*; and ſo of the oranges, yellows, &c. ſince, in every caſe, the ſlighteſt deviation from the thickneſs or ſize of particles ſtated as eſſential to the production of a particular colour, ought to occaſion the appearance of that colour which is next in the ſeries above or below. But nothing like this is any where attempted, nor is there any thing in nature acceſſible to human obſervation, which could in any degree juſtify the attempt.

are, I can readily point out ſeveral, which, on his own improbable, or rather impoſſible ſuppoſitions of mechanical attenuation or incraſſation, and nothing elſe, from chymical agents, cannot be reconciled to his theory, even by the aſſiſtance of Sir Iſaac Newton's convenient table. The green leaves of the anil and glaſtrum, he ſays, "being long ſteeped in water, their parts are *diſſolved* into a blue ſubſtance, which is indigo and woad." Now the truth is, that the blue ariſing from theſe vegetables is not the reſult of any *diſſolution*, but of an abſorption of air during the fermentation which they undergo; and this colour does not manifeſt itſelf until there is a beginning *aggregation* and *concretion* of its matter into *larger* particles, which becoming *denſer*, as well as *larger*, ſink down to the bottom, leaving the water colourleſs. So that here the change from green to *blue*, is manifeſtly accompanied with an increaſe both in the ſize and denſity of the coloured particles, which is abſolutely incompatible with Mr. Delaval's hypotheſis; ſince, according to the table in queſtion, every change of colour from green to blue is the effect of a *diminution*, not an *increaſe*, in the ſize and denſity of its particles. When the indigo itſelf (formed into large dry maſſes) is to be diſſolved for dying, by the combined action of *cauſtic* alkalies, and of particular chymical attractions, or of vegetable ferments, the ſolution, though manifeſtly attended with a diviſion or diminution of the coloured particles (as well as a loſs of the air abſorbed during the firſt proceſs) becomes green, contrary to the table and hypotheſis in queſtion; and in this ſtate it is applied by the dyers to wool, and other ſubſtances, to be dyed; and theſe, when firſt taken out and expoſed to the air, appear green; but by abſorbing, and uniting with a portion of it, they immediately become blue, and in doing ſo, the divided particles again concrete into larger ones, as muſt be evident, among other proofs, from this, that the ſurface of the indigo liquor on which the air has an immediate action, is from that cauſe always blue; and if we ſkim off this blue matter from the ſurface (which is nothing but indigo) it will be found impoſſible to make it enter the pores of any ſubſtance to be dyed, ſo as to dye a colour therewith; becauſe the particles having regained, and recombined with their proper portion of pure air, or its baſis, and with each other, are no longer ſufficiently divided and diſſolved for that purpoſe; ſo that in all theſe caſes, the matter of indigo becomes more denſe, and its particles larger, in paſſing from green, to the more refrangible colour, blue; and the contrary, in paſſing from blue to the leſs refrangible colour, green. And this too is the caſe, when the infuſions of rhubarb, turmeric, &c. are made "to deſcend (as he expreſſes it) from yellow to orange and red," "by the addition of an alkali," which, whatever he may imagine to the contrary, *diſſolves* theſe colouring matters more powerfully than any acid. Similar objections occur in oppoſition to the inſtances which Mr. Delaval alleges, reſpecting "the changes of Colour which animal ſubſtances undergo." Among theſe, *e.g.* he obſerves, that cows milk, boiled up with an alkali, changes from white to yellow orange and red; and, as uſual, he gratuitouſly ſuppoſes, that, in producing theſe changes, it acts by *incraſſating* or

coagulating

coagulating the milk; though if, contrary to all probability, alkalies were able to do this, we have no reafon to conclude that fuch coagulation would render the milk either yellow, orange, or red, becaufe no fuch colours appear when it really is coagulated by acids, &c. as in the making of curds and cheefe. But furely it cannot be neceffary for me ferioufly to combat fuch chimeras any longer. The common fenfe and experience of mankind, if fairly confulted, will condemn and revolt at the idea of making the colours of bodies depend on their weight, or the fizes of their particles; for it certainly never has been obferved that the heavieft fubftances were red, or the lighteft violet-coloured, or that bodies equally heavy were all of the fame colour. Different parcels of indigo, for inftance, vary confiderably as to fpecific gravity, without any variation of colour; and therefore it muft be very eafy to find fome of thefe agreeing in that refpect exactly with the colouring matter of cochineal (carmine), which of all colours is the fartheft removed from that of indigo: and if Mr. Delaval fhould allege, that, though agreeing in weight, they differ as to the fize of their refpective particles, let him correct this difference by the only means fuited to do it, without doing more; I mean by fimple mechanical divifion, trituration, or grinding. Let this be employed upon either of the fubftances in queftion as long as he fhall think proper, and let us then fee whether he can thereby render the colour of indigo red, or that of cochineal blue or violet. Let him alfo make a fimilar trial upon mineral ethiops and vermillion; the one black, and the other of a beautiful red colour,

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though both are compofed of mercury and fulphur; and both are, or may be eafily rendered of exactly the fame fpecific gravity, by a little alteration in the ordinary proportions of their conftituent parts.

Should what I have faid on this fubject prove infufficient to convince any one of my readers, I only beg that he will follow me, with a mind open to conviction, through the various inftances, which, for other purpofes, I fhall have occafion to ftate hereafter, of colours produced, or changed by means and in ways that are wholly irreconcileable to the theory in queftion, and I perfuade myfelf that his doubts and difficulties will be effectually removed, fo far as they may relate to the truth or fallacy of Mr. Delaval's hypothefis, of which I mean hereafter to be filent, becaufe I cannot, without pain, fupport even the appearance of contention. And indeed I feel it neceffary to apologize for having fo long detained my readers on this fubject: I have done it not only from a conviction of the truth of what I have written, but from the belief of its being expedient to refute an hypothefis, incompatible with a confiderable part of what I am about to offer to the public; an hypothefis which the name and authority of Sir Ifaac Newton had pre-eminently fanctioned; which the learning and talents of Mr. Delaval had rendered plaufible; and which even at prefent is, I believe, generally confidered as true, in this and other countries. Should there be found any feeming incivility towards Mr. Delaval, I hope it will be confidered as the unguarded effufion of a zeal for truth. Nothing is farther from my

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wiſhes than a perſonal contention with that Gentleman, though I have thought it neceſſary to combat an error, capable of obſtructing the progreſs of ſcience. I have never had the honour of his acquaintance, but I have long reſpected his character and abilities; and though I think he has erred, I alſo think it may be deemed a matter of excuſe and conſolation that he has only erred with Newton.

Having, as I think, ſhewn that the permanent colours of different objects do not ariſe from their denſities, or the ſizes of their particles, it becomes me to ſtate ſuch facts and obſervations as ſeem beſt ſuited to throw light upon this obſcure and very intricate ſubject.

Sir Iſaac Newton having found that inflammable ſubſtances poſſeſſed greater refractive powers than others, in proportion to their denſities, ſays, in his ſecond Book of Optics, that " it ſeems rational to attribute the refractive power of all bodies, chiefly, if not wholly, to the ſulphureous parts with which they abound; for, adds he, it is probable that all bodies abound more or leſs with ſulphurs;" a term by which he intended to diſtinguiſh inflammable matters generally. And this great man having alſo concluded that the permanent colours of natural bodies were analogous to the colours produced by the refractions of thin, colourleſs, tranſparent plates, &c. chymiſts were generally induced to make all colour depend on the principle of inflammability or phlogiſton, which, until very lately, was ſuppoſed to exiſt in metals and other ſubſtances, where there certainly is no evidence

evidence or appearance of it; and in thoſe caſes where the total want of inflammability was manifeſt, they *confounded* this with the *matter* of heat and that of light; to both of which they aſcribed the power of *phlogiſticating* other ſubſtances, and of thereby producing or changing their colours: a ſpecies of confuſion ſuited only to cover and perpetuate ignorance; ſince every ſingle colour is found to belong both to combuſtible and incombuſtible ſubſtances, and to neither excluſively. The *combuſtible* diamond, which Sir Iſaac Newton conjectured to be "*an unctuous ſubſtance* coagulated," is found to be of almoſt all the different colours, whilſt other gems, though of ſimilar colours, are all *incombuſtible*. Combuſtible indigo, and incombuſtible ſmalt, are both blue; combuſtible vermillion and incombuſtible minium are both red; combuſtible gamboge, orpiment, &c. are yellow; and ſo are certain incombuſtible oxyds of lead, iron, and mercury. But ſince the exiſtence of phlogiſton in metals, &c. has been denied by the pneumatic chymiſts, they have in moſt caſes attributed the origin and changes of colours to the application or combination of different airs or gazes, and particularly oxygene in different proportions; and it has been ſuppoſed that theſe gazes poſſeſſed conſiderable *refractive* powers, and were *thereby* enabled to produce effects on colours like thoſe which the followers of Stahl had imputed to phlogiſton; and Mr. Berthollet, in his recent work on the Elements of Dying, intimates, that "many important obſervations ſtill remain for thoſe who would follow the ſteps of that great man (Sir Iſaac Newton), and compare the *refracting* powers of the different gazes, and other ſubſtances, the conſtituent principles of which are now known." But from all that I can diſcern of this intricate ſubject, it ſeems to me, that, though the priſm, and other tranſparent colourleſs ſubſtances, in different forms, ſhew us the different colours of the ſeveral rays of light, by *ſeparating* them from each other, in conſequence of their greater or leſs refrangibility, or diſpoſition to be "turned out of their way, in paſſing out of one tranſparent body or medium into another," yet I am perſuaded that the *permanent* colours of different bodies, or ſubſtances, *are not produced by mere refraction*, and that Sir Iſaac Newton was miſled by analogy when he extended his diſcoveries and concluſions reſpecting the tranſient colours reſulting from the refractions of light by pellucid colourleſs ſubſtances, to the permanent colours of various kinds of matter; ſince the latter evidently depend on other properties, which determine, or occaſion the reflection or tranſmiſſion of ſome particular ſort or ſorts of rays, and an abſorption or diſappearance of the reſt; and theſe I conceive to be certain *affinities*, or *elective attractions*, exiſting in or between the differently coloured matters and the particular ſorts or rays of light ſo abſorbed or made *latent*; and of which many inſtances and proofs will, I think, be found in the ſubſequent parts of this work. Next after the diamond and amber, we find that ſpirit of turpentine, lintſeed oil, olive oil, camphor and alcohol, or rectified ſpirit of wine, poſſeſs greater refracting powers, in proportion to their reſpective denſities, than any of the other ſubſtances contained in Sir Iſaac Newton's table, and yet

they

they are all *permanently destitute of colour*; a fact which does not seem to indicate any connexion between the refractive power of a substance and its natural *permanent colour*. Nothing seems to act so powerfully and extensively in producing and changing those affinities, or elective attractions, from which the permanent colours of different substances arise, as pure vital air, or its basis, the oxygene; which indeed seems to owe its elastic, or aërial form, to a portion of light as well as heat. Scheele demonstrated that gold, silver, &c. were revived from their oxyds by the contact of light; and Mr. Berthollet has proved, that, in producing this effect, the light occasions a separation of oxygene, in the form of pure vital air. Light also, by giving elasticity to oxygene, separates it from various other substances, to which it would otherwise remain united, under, perhaps, the greatest degrees of heat. A bottle filled with oxygenated muriatic acid, improperly called dephlogisticated marine acid, if it be exposed to the light, lets go its oxygene, and becomes common muriatic acid, but if wrapped in black paper, and exposed to the sun, it suffers no change; and if heated in the dark, it will fly off in the form of oxygenated muriatic gas, without any decomposition of its oxygene.

We are at this time well acquainted with the constituent parts of the acid of nitre: it undeniably consists of what the pneumatic chymists term azote (phlogisticated or nitrous air), rendered acid by its combination with a certain portion of oxygene, or the basis of vital air. When the azote and the oxygene are combined

bined in a certain proportion, the acid or compound is colourlefs, as we fee it in aqua fortis, or nitric acid: but if this colourlefs acid, in a tranfparent glafs veffel, partly filled, be expofed to the rays of the fun, or the light of a fire, an alteration will take place in the proportion of its ingredients; fince the light will combine with a part of the oxygene, and caufe it to become elaftic and fly off, and the azote will confequently predominate in the remainder; which, merely in confequence of this predominance, will affume firft a yellow, then an orange, and afterwards a high vivid aurora, and even a red colour, intenfely affecting the fight. But if the glafs veffel containing the colourlefs nitric acid, were filled with it, no fuch change of colour would take place by any degree of expofure to the fun's rays or other light; becaufe, in this cafe, there would be no fufficient fpace or room to allow of a feparation and efcape of the oxygene. When nitrous acid has been made to affume the colours as before mentioned, if the glafs veffel containing it be hermetically fealed and kept for fome time in the dark, the oxygene, by lofing its light, will lofe its elafticity; and being again reabforbed by the nitrous acid, the latter will become colourlefs, as before. Mr. Keir mentions an orange-coloured nitrous acid, which, by long keeping, became green, and afterwards of a deep blue; and Bergman fays, that if, to a concentrated red nitrous acid, one fourth part of the quantity or meafure of water be added, the colour will be changed to a fine green, or to a blue, by the addition of an equal meafure of water, and that double its quantity of water will deftroy the colour. Here then we have an example of all the various colours produced by the two ſpecies of air which compoſe our atmoſphere (almoſt wholly) when deprived of their elaſticity, and mixed in particular proportions with more or leſs dilution by water.

In the ſame manner, colourleſs nitric acid, when applied to wool, ſilk, fur, or the ſkins of animals, their nails, horns, &c. renders them all not only yellow, but orange, and even aurora-coloured. Mr. Berthollet thinks theſe changes are produced by a kind of combuſtion; but I am perſuaded they are the reſult of a combination of the oxygene with the azote, which he has proved to be a conſtituent part of all animal ſubſtances; they being exactly ſimilar both in their nature and origin, to the changes of colour produced as before mentioned in the nitrous acid. Were theſe colours the effect of combuſtion, why are they not likewiſe produced in the ſame manner upon linens, cottons, and vegetable ſubſtances, which contain either little or no azote, but a great portion of the baſis of charcoal, and ought therefore to be more liable to be acted upon in the way of combuſtion, than animal ſubſtances?

Long before the properties of the ſeveral kinds of air were known, many changes of colour had been noticed as produced by the application or action of light; and indeed its effects are ſo remarkable, in a multitude of caſes, that no one can doubt of its powerful agency in theſe and other reſpects. The only thing to be aſcertained on this point is, whether the colours which

which accompany or require the application of light, reſult directly from a combination of it with the coloured ſubſtance, or indirectly from its particular action in occaſioning a ſeparation of airs, or their baſes (and particularly of the oxygene), or by favouring a combination thereof with the coloured matter. Mr. de Luc maintains, that light enters mediately or immediately into the compoſition of a conſiderable number of ſolids, and of all liquids and expanſible fluids, particularly the æriform; and it ſeems reaſonable to conclude, that it muſt greatly influence many phyſical and chymical phenomena. That able chymiſt Mr. Chaptal, found that the rays of light directed particularly upon certain parts of glaſſes, containing ſolutions of different ſalts, cauſed them to cryſtallize upon thoſe ſides which were in contact with the light, and no other. Many ſubſtances abſorb and retain large portions of light, as appears by their emitting it in the dark; this is the caſe of the Bolognian ſtone, and of many other natural as well as artificial compoſitions; among the latter, Mr. Canton's phoſphorous (compoſed chiefly of calcined oyſter ſhells) imbibes and retains the light ſo ſtrongly, that, after being expoſed to it for only a few ſeconds, it continues to be luminous even at the end of ſix months. Almoſt all animal and vegetable ſubſtances are found to emit light in certain ſtages of putrefaction, or decompoſition, and therefore it may be preſumed to have been previouſly combined with ſome of their parts; but how it acts, or whether it acts at all immediately, in producing the colours of any object, ſeems yet uncertain; though we know that it does contribute greatly

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to the production or change of colours in a multitude of mineral, vegetable, and animal fubftances; in fome cafes, by combining with the bafis of vital air (oxygene), and feparating, by rendering it elaftic; and in others, by promoting the action and union thereof, upon or with particular fubftances. It feems difficult to afcertain the particular affinities by which fometimes the one, and fometimes the other, of thefe effects is produced: perhaps they depend on caufes to which chymical knowledge, in its prefent imperfect ftate, cannot reach.

From the experiments of Beccari, Meyer, Schulze, Scheele, and Sennebier, it appears that muriate of filver (horned filver), which is nearly of a pearl white, changes to a violet colour, and from thence to a black, in the fpace of a very few minutes, when expofed to the fun's rays in a tranfparent glafs; and this change Sennebier afcribes folely to the action of light; fince, as he maintains, the muriate of filver will invariably retain its whitenefs, though expofed either to heat or cold; and in a moift or a dry air, or in *vacuo*, if fecured from the acceffion of light, and of what he calls phlogiftic vapours (probably fulphurated, hydrogenous gas), and that it lofes its whitenefs only by the application of light, and then only in proportion to its quantity or intenfity; fo that when the fun's rays are copioufly applied by a lens, the muriate of filver is rendered violet coloured in a fingle fecond. By covering the muriate of filver with four thickneffes of white paper, its whitenefs was preferved; one, two, and three thickneffes retarded, but did not prevent its finally becoming violet and black. Mr. Sennebier found that the different rays of light, under the fame circumftances, coloured the muriate of filver with different degrees of celerity; *i. e.* the violet rays in 15 feconds, the purple in 23 feconds, the blue in 29, the green in 37, the yellow in 5 minutes and 30 feconds, the orange in 12 minutes, and the red in 20; but the rays of the three laft colours would not, as he relates, produce fuch a dark violet colour in any length of time, as was thus quickly produced by the more refrangible rays. I have alfo witneffed moft of thefe, and fome other changes of colour, taking place in muriated or horned filver, and which may, I think, be fatisfactorily explained, by confidering that this preparation is the oxyd or calx of that metal, united only to a very fmall portion of either oxygene or muriatic acid, which the light renders elaftic, and thereby feparates fuch a portion of it as to produce an incipient reduction or revival of the metal, and with it the dark colours which filver always manifefts in that ftate; and in confirmation of this, I need only mention what I have feveral times obferved, that though muriated filver, placed at the bottom of a colourlefs glafs veffel, nearly filled with water, was made violet coloured in about two minutes, by the weak light of a room, having a fingle window only, and in a cloudy day; yet a direct application of the fun's rays for many days produced no change of colour, when the muriated filver was covered with muriatic acid inftead of water; becaufe, in this cafe, nothing like a revival of the filver could take place, whilft fo much uncombined muriatic acid remained in contact with it, and ready to ſupply the place of any which might be ſeparated by the ſun's rays.

It is curious to obſerve the different degrees of force and celerity with which, according to Sennebier, the different rays of light change the colour of horned ſilver, *exactly in* proportion to their degrees of refrangibility; an effect which muſt be aſcribed to a greater affinity between the leaſt refrangible ray and the muriatic acid, in conſequence of which the former more readily combine with and extricate or ſeparate the latter from the ſilver to which it was united.

A ſolution of ſilver in the nitric acid likewiſe changes colour by the action of light, and becomes black *thereby*, as well as by the application of inflammable ſubſtances, of calcareous earth (chalk), and every thing elſe which can ſeparate a ſufficient portion of the oxygene. It alſo gives the ſkin a black colour, which cannot be effaced, but by a removal or change of the ſkin itſelf: it tinges the hair, nails, and other animal ſubſtances, in like manner, becauſe they occaſion a ſeparation of ſo much of the oxygene as is neceſſary for that purpoſe.

Mercury diſſolved in nitric acid, being waſhed with water, affords a yellow oxyd, which, when expoſed to the light in a tranſparent colourleſs glaſs veſſel, will become black on the ſide to which the light is applied, even where the veſſel is filled with water; becauſe, as in the caſe of horned ſilver, the light extricates a part of the oxygene; this yellow oxyd being a preparation of mercury, with but a very ſmall proportion of acid,

acid. The red precipitate, and ſeveral other preparations of mercury, have their colours changed even under water, by ſimilar means. The white or colourleſs ſolution of mercury, by the nitric acid, when applied to animal and inflammable ſubſtances, tinges them purple and black, in the ſame way, and from the ſame cauſe, as they are tinged by the ſolution of ſilver. Similar effects happen with the ſolution and oxyd of biſmuth, which laſt is therefore uſed to blacken hair when mixed with pomatum. Almoſt all the other metals afford inſtances of changes of colour more or leſs remarkable, depending upon the acceſſion and ſeparation of oxygene; and in many of which light has a conſiderable influence in promoting one or other of theſe effects. In all the inſtances lately mentioned, however, blackneſs was produced by a ſeparation of air from the metallic baſis; but there are others in which it reſults from the addition or acceſſion thereof. Arſenic, as Mr. Chaptal mentions, when firſt ſublimed, is of a ſhining grey, or ſteel colour, but blackens ſpeedily in the air (" noircit promptement a l'air"); and he likewiſe obſerves, that " manganeſe, precipitated by an alkali from its ſolution, was found to be a whitiſh gelatinous ſubſtance, which ſoon changed colour, and became *black*, by the contact of air; that, having been a witneſs of this phenomenon, he could only attribute it to the abſorption of oxygenous gas, and found this to be the caſe, by ſhaking the white precipitate in glaſſes filled with that gas, by which the black manifeſted itſelf in one or two minutes, and a conſiderable part of the gas was found to have been abſorbed." Elemens de Chymie, tom. ii. p. 260.—

The preceding inſtances relate to mineral and inorganical ſubſtances, though in the two laſt it muſt be owned, that the influence of light (the immediate object of conſideration) is not very evident; and therefore I ſhall proceed to notice ſome of the more remarkable effects of that element, in producing the colours of vegetable and animal ſubſtances. Ray, in his Hiſtoria Plantarum, printed in 1686, vol. i. p. 15. appears to have diſcovered, by ſeveral experiments and obſervations, that the green colour of plants depended chiefly upon the influence of light: he had found that they were *green*, whilſt vegetating under a tranſparent glaſs bell expoſed to the light, and that when growing in obſcurity under an opaque veſſel, they loſt their green, and acquired a pale whitiſh yellow; their ſtalks, at the ſame time, becoming long, ſlender, and feeble, and their leaves ſmall. And theſe effects he aſcribed to the want of light, rather than of either air or heat. "Nobis tamen non tam aer quam lumen, luminiſve actio coloris in plantarum foliis viridis cauſa eſſe videtur."—"Ad hunc autem colorem inducendum non requiritur cœlor," &c. Mr. Bonnet has ſince confirmed Ray's concluſions upon this ſubject, and added ſeveral curious facts, reſulting from a variety of experiments related in the fourth and fifth volumes of his works: but it is Mr. Sennebier who has done moſt, and carried his inquiries fartheſt reſpecting it, as appears by his "Memoires Phyſico Chymiques ſur l'Influence de la Lumiere Solaire," &c. in 3 vols. 8vo.

It is now well aſcertained, that vegetables, growing in the light, give out the oxygenous gas

(pure

(pure vital air); and Dr. Ingenhouz, by a great number of experiments, has proved, or conceives himſelf to have proved, that in the dark they give out the carbonic acid gas (fixed air); though this has been doubted by others, and particularly by Mr. Sennebier, who conceives, that, in theſe caſes, it was the pure air vitiated by ſome diſeaſe or decompoſition of the plant itſelf: Dr. Ingenhouz, however, in his laſt publication, adheres to his former opinion, and ſupports it with new facts and arguments. Be this, however, right or wrong, there is no room to doubt but that healthy plants, growing in the light, decompoſe both water and carbonic acid gas; and, appropriating to themſelves the hydrogene, or inflammable air (which is a conſtituent part of water), and the carbonaceous matter, or baſis of the carbonic acid, with perhaps a ſmall portion of the oxygene, they emit the reſt in the form of vital air, which the light ſeems to ſeparate, by combining with and rendering it elaſtic, in the ſame manner as it ſeparates the oxygene from the calces or oxyds of metals, &c. But when plants vegetate in obſcurity, no ſuch ſeparation can take place: indeed the water imbibed by the plants ſeems not to be properly decompoſed, unleſs its living powers be aided by the ſtimulus of light, and by its affinity for the oxygene. There is, therefore, an accumulation of this latter ſubſtance, and a want of inflammable air to compoſe the reſinous matter, by which the green colour of the plant is produced; and this colouring matter being very ſparingly formed, and at the ſame time combined with an exceſs of oxygene (which generally weakens or deſtroys vegetable colours), the plant, inſtead of its natural greenneſs, exhibits only a pale ſtraw colour. Mr. Sennebier found that plants, in this ſtate, received a deeper green, and in leſs time, by expoſure to the violet rays of light, than to thoſe which were leſs refrangible, as was the caſe in colouring the muriate of ſilver. He alſo found that plants left to vegetate without light, under veſſels filled either with azote (phlogiſticated air), or with hydrogene (inflammable air), did not loſe their green colour, as when ſurrounded by common atmoſpheric air. In carbonic acid (fixed air) they ſoon periſhed. Dr. Ingenhouz alſo obſerved, that on mixing a little inflammable air with either the common or the vital air in which a plant was growing, under a tranſparent glaſs, the green colour of the plant ſoon became deeper. In theſe caſes there ſeems to have been an aſpiration or abſorption of the inflammable air, affording an increaſe of the reſinous colouring matter.

Mr. Sennebier alſo found, that the red tinctures of orcanette *, ſafflower, kermes, gum lac, and cochineal, were made yellow by expoſure to the ſun's rays; and the tincture of dragon's blood was thereby deprived of all colour: in theſe caſes the alcohol, or ſpirits of wine, aſſiſted the action of the ſun's rays in decompoſing the ſeveral colouring matters, probably by combining with their oxygene; becauſe it was found that the *aqueous* infuſions of orcanette, kermes, and cochineal, ſuffered no change by the like expoſure; though indeed the infuſions of ſafflower, dragon's blood, and gum lac, were changed by it; perhaps becauſe they contain a

* *Anchuſa tinctoria.* Lin.

reſinous

resinous matter which might have co-operated with the rays of light, in the same way as the spirit of wine is supposed to have done. Mr. Sennebier observed, that the petals of damask roses afforded a kind of brick colour to spirits of wine, when put into it; and that this, by a few minutes exposure to the common light, became of a fine violet-colour; which, however, was soon destroyed, by a direct application of the sun's light, unless when a few drops of some of the strong acids were added; in which case, the colour withstood the sun's rays for several months. From these instances I conclude, that the colour of the roses depends on a certain proportion of oxygene; that the light, aided by the attraction which spirits of wine, as well as other inflammable matters, have for oxygene, separates it and destroys the colour; but that these effects are prevented, as might be expected, by the addition of acids containing and affording a supply of oxygene. And that this was the fact, seems evident from this observation, made by Mr. Sennebier, that when the petals of the roses had been rendered white by imparting their colour to the spirit of wine, they regained it on being taken out, and exposed to the air, even in a dark place; though they did it much quicker in the light; but not at all in a vessel containing only azote, surrounded by quicksilver, even when aided by an immediate application of the sun's light; which clearly proves, that the restitution of oxygene was indispensably necessary to the restitution of their colour. In the same way sulphureous acid whitens roses, by abstracting and depriving them of their oxygene; and the sulphuric acid restores the colour, by restoring the oxygene[6]. Mr. Sennebier alſo found the red ſkins of peaches to whiten in ſpirits of wine, like the petals of roſes, and, like them, to regain their colour by expoſure to the air; as did alſo the red ſkins of plumbs. He likewiſe obſerved, that the water-colours uſed by painters, if covered by a ſolution of fiſh-glue or iſinglaſs, and then varniſhed, withſtood the action of the ſun's rays much longer than if varniſhed without the fiſh-glue; which laſt ſeems to prevent the varniſh from co-operating with the light in extricating the oxygene of the colouring matters, as, from its inflammable nature, it would do, if in immediate contact with them. The preceding are examples of colours produced, changed, or deſtroyed by the action or affinity of light, exerted in ſeparating, by giving elaſticity to, the oxygene or baſis of vital air. There are many other caſes, however, in which the affinity of light is very differently exerted, and in

[6] The ſulphureous or volatile vitriolic acid, not being ſaturated with oxygene, is diſpoſed to attract it from other matters in contact with it; and by ſo doing, it not only whitens roſes, but ſilk, wool, and other ſubſtances, rendered yellow by being united to a certain portion of oxgene: and theſe ſubſtances, being ſo whitened, may again be made yellow by the application of oxygenated muriatic acid, which will reſtore to them that portion of oxygene of which they had been deprived. Hence it appears, that the application of oxygene, which ſo powerfully bleaches linen, is equally efficacious in producing a contrary effect on ſilk and wool; I mean that of deſtroying their whiteneſs, and rendering them yellow. And theſe oppoſite effects ariſe from a difference in the ſubſtances acted upon by the ſame agent, the whiteneſs of wool and ſilk evidently depending upon the abſence of oxygene, and that of linen and cotton upon its preſence; perhaps upon their being completely ſaturated with it.

which that element, inftead of decompofing the oxygene, and carrying it off from particular matters, contributes rather to attract it, and promote its combination with them, probably by uniting itfelf to the fame matters (in confequence of fome particular affinity), and forming, together with the oxygene, a triple compound. The green colour of the leaves of plants refides in a refinous fubftance, which being diffolved and extracted by fpirits of wine, produces a green tincture; and Mr. Sennebier having expofed this to the rays of the fun, in a clear tranfparent glafs, but half filled, he found, upon repeated trials, that the colour was generally deftroyed in about twenty minutes, and a yellowifh fubftance was precipitated to the bottom; which I conceive to have been the colouring matter faturated with oxygene: but if the glafs was completely filled with the green tincture, and clofely ftopped, Mr. Sennebier found, that the ftrongeft action of the fun's rays upon it, during four months, was not fufficient even to weaken in any degree the green colour, becaufe all oxygene was excluded, and the rays of light, without it, were unable to effect any change. If azote (phlogifticated air) was inclofed in a veffel partly filled with this green tincture, the latter fuffered little or no change by long expofure to the direct action of the fun's light; but if, inftead of this, he fubftituted pure vital air, the green colour was moft rapidly deftroyed. Mr. Sennebier alfo found, that the dark red juice of black cherries very foon loft its colour, when expofed to the fun's rays, but that a tincture of thofe cherries in fpirit of wine preferved its colour, in the fame circumftances; the fpirit of wine, as I conceive, affording a covering and defence to the

the colouring matter of the cherries againſt the action and farther combination of oxygene or vital air. Here the effect was directly oppoſite to that of roſes, lately mentioned. There are many other inſtances of abſorption of oxygene promoted by the action of light: many of theſe I ſhall have occaſion to mention hereafter for other purpoſes, and therefore will content myſelf at preſent with noticing two experiments made by Mr. Berthollet. In the firſt, he "inverted, over mercury, a bottle half full of the green ſolution (employed by Mr. Sennebier), and expoſed it to the light of the ſun; when the colour was diſcharged, the mercury was found to have *riſen in the bottle*, and conſequently vital air had been abſorbed; the oxygene having united with the colouring matter." In the ſecond experiment, he "placed a tincture of turnſol, in contact with vital air, over mercury, both in the dark, and expoſed to the light of the ſun; the former continued unchanged for a conſiderable length of time, and the vital air had ſuffered no diminution; but the other loſt much of its colour, became red, and the air was in a great meaſure abſorbed, &c.

In the ſame manner that plants, firſt ſhooting out of the earth, are white, ſo negro children, when firſt born, are likewiſe of that colour, but by expoſure to light and air, they in a few days become black; and as far as I can judge from what I have ſeen of the effect, it ſeems to reſult from a combination of air, with a particular matter or baſis, compoſing a part of the reticular membrane under the ſkin, and fitted by Nature to become black in this way, as that of the European is to remain white, or that of the aborigines

aborigines of North America to be brown, &c. The blacknefs of the negro children is found, by obfervation, to be confiderably haftened by early expofure to ftrong light, which feems to favour the abforption, or combination of oxygene; an effect which is not furprizing, fince, by many of Mr. Sennebier's experiments, the light was found to act in this way through coverings of greater thicknefs than thofe which oppofe its accefs to the reticular membrane in negroes.

The action of light upon the human European fkin, is alfo ftrongly manifefted by the production of tan and freckles; of which the latter appear likewife to reach as far as the reticular membrane. Thefe effects are the moft remarkable in fea voyages, and other fituations where the light is copioufly reflected, efpecially by water, though without any increafe of heat. In like manner the hair of kittens, puppies, &c. though fitted by nature to become black, is, immediately after birth, only of a brownifh black colour, which gradually darkens externally, or as far as it is expofed to the air and light, but no farther; for I have found the blackeft cats and dogs, even in old age, to have that part of their hair which is neareft the fkin, and moft fecluded from air, particularly towards its roots, only of a brownifh black colour, very different from what is feen at the ends or points.

Mr. Sennebier mentions, upon the authority of Scheele, that the nereis lacuftris is red whilft living in places acceffible to the fun's rays, and white when living in obfcurity. And M. Dorthes (fee Ann. de Chymie, tom. ii.) affirms, that

that moſt of the larvæ of inſects inhabiting the interior cavities of animals, as well as of woods, fruit, the earth, &c. are white, and that having forced many of them to live under tranſparent glaſſes, expoſed to the light, their whiteneſs was gradually changed for brown colours; and that the tree frog, which generally lives in the ſhade, being forced to live in a ſituation expoſed to the ſun-ſhine, changed his colour from a yellowiſh, to a very dark green. In theſe laſt inſtances it does not appear certain whether the light produces the changes of colour which have been juſt mentioned, by occaſioning an abſtraction or an addition of oxygene, but from what we know of its effects, in caſes apparently ſimilar, we may at leaſt conclude that it acts in one or the other of theſe ways. *Yellow* ſilk, according to Mr. Poivre's account, taken from the cocons and expoſed to the ſun, ſoon becomes perfectly white; and the ſame happens to ivory, if expoſed in like manner, after it has become yellow. Theſe effects are ſimilar to thoſe which occur to white cotton garments, and to white lead paints, which notoriouſly become yellow, if deprived of the free acceſs of light and air for any length of time, but are again rendered white, by whatever reſtores to them the oxygene which is wanting to maintain their whiteneſs.

I have now noticed the principal facts reſpecting the action of light in producing or changing the colours of minerals, vegetables, and animals; and as far as our knowledge extends, it does not appear warrantable to conclude that light contributes to theſe effects, otherwiſe than by its affinity with oxygene, which, (affinity,) under ſome circum-

circumſtances, and with the aid perhaps of other unknown affinities, ſometimes ſeparates and renders the oxygene elaſtic by uniting with it, and at other times occaſions the combination of an increaſed portion thereof with the coloured ſubſtance. This laſt effect is what Mr. Berthollet ſeems exclusively to inſiſt upon, as occaſioning, either with or without the aid of light, all the changes and injuries to which animal and vegetable colouring matters are liable; and he deems the action and effects of oxygene in theſe caſes to be ſimilar to thoſe of *combuſtion*. "In conſidering the effects of air on colours (ſays he), it is neceſſary to make a diſtinction between thoſe produced by metallic oxyds, and thoſe produced by the colouring particles," meaning thoſe of a vegetable nature; the modifications of the former are "entirely owing, continues he, to different proportions of oxygene;" but I have been led by obſervation, he adds, "to form a different opinion of the latter," with which the oxygenated muriatic acid had exhibited different phenomena, ſometimes diſcharging their colour, and producing whiteneſs, but moſt frequently rendering them yellow, fawn, or root-coloured, or brown or black, according to the intenſity of its action: and he remarks, that he had found, by compariſon, that when the colouring particles were rendered yellow, root-coloured, or brown, by the oxygenated muriatic acid, effects were produced ſimilar to thoſe of combuſtion; and that they were "owing to the deſtruction of the hydrogene, which, as it combines with oxygene more eaſily, and at a lower temperature than charcoal does, leaves the latter *predominant*; ſo that the *natural colour of charcoal* is

more

more or leſs blended with that which before exiſted[7];" And as "the light of the ſun conſiderally accelerates the deſtruction of colours," he concludes that it ought, if his theory be well founded,

[7] Meſſ. Lavoiſier, Berthollet, and other pneumatic chymiſts, ſeem to conſider the *black* colour of charcoal as natu-ally belonging to the vegetable matter from which it is ormed, and not as the reſult or effect of combuſtion. To me, however, charcoal ſeems to be a kind of vegetable *oxyd*, conſiſting of the carbonaceous baſis, united to a certain portion of oxygene, enough to render this baſis black (as it occaſions the blackneſs of manganeſe), but not enough to ſaturate and convert it into carbonic acid gas. Hard woods contain ſo great a portion of the baſis of charcoal, that if it really exiſted therein, with its black colour, previous to combuſtion, it is impoſſible to conceive how they ſhould ever appear white, yellow, red, &c. ſince in dying, &c. we find, that laying other colours upon a black ground, only increaſes the blackneſs. Neither do I think that this blackneſs is the only circumſtance in which charcoal differs from its baſis, or the ſtate in which the vegetable part thereof exiſted previous to combuſtion: on the contrary, I am perſuaded that its oxydation, or combination with oxygene, gives it new and very remarkable properties. Mr. Fourcroy has informed us (ſee Ann. de Chymie, tom. v.), that the aqueous extracts of ſeveral colouring matters, by being left for a conſiderable time expoſed to air, acquired and combined with a conſiderable portion of oxygene, and thereby aſſumed new colours, and at the ſame time became themſelves much more fixed and permanent than before; which ſeems to be the caſe (though in a greater degree) of the vegetable baſis of indigo and that of charcoal. This laſt is indeed never converted into charcoal, but by ſuch a degree of heat as muſt neceſſarily occaſion its combination with oxygene (which never can be wanting, even in cloſe veſſels, becauſe it exiſts in the air veſſels, and other parts of all vegetables); and when this converſion is made, the charcoal is rendered infinitely more indeſtructible than any other vegetable matter, as it will reſiſt the combined action of ſun, air, moiſture, &c. for hundreds of years; and indeed it can hardly be deſtroyed but by ſuch farther combuſtion as will change it into carbonic

founded, "to favour the combination of oxygene, and the combuftion thereby produced *."

In thus afcribing the decays of vegetable and animal colouring matters in general to effects or changes fimilar to thofe of *combuftion*, Mr. Berthollet, in my opinion, has gone much further than is warrantable by facts. It cannot, I am perfuaded, be his intention that we fhould apply the term of combuftion to alterations which refult from a fimple addition of oxygene, to colouring matters, without a deftruction or feparation of any of their component parts; though a great many of the decays and extinctions of thefe colours evidently arife only from fuch fimple additions of oxygene. The nitric, fulphuric, and other acids containing oxygene, have the power not only of weakening, but of extinguifhing, for a time, the colours of many tingent matters; not however by any effect which can properly be denominated a combuftion, but rather by a change in their feveral affinities or attractions, for particular rays of light in preference to other rays;

ric acid gas. This indeftructibility, as well as the black colour of charcoal, feem therefore to refult from the combination of oxygene with its bafis. Were not this the cafe, and did it really exift with its black colour naturally in vegetables, why do we not find it remaining intire after the other parts of vegetables are feparated or deftroyed by fermentation, putrefaction, &c.? and why does it diffolve and rot with them undiftinguifhed, and contrary to what happens when it exifts feparately, in the form of charcoal? and why, when in this form, will it not recombine with matters fimilar to thofe feparated from it, and enter with them into fermentation, &c. as it furely ought to do if it had acquired no new property, and only been left in a diftinct form, by the fimple abftraction of thofe matters?

* Elements of the Art of Dying, chap. iii.

but none of their parts being deſtroyed, or carried away, the addition of an alkali, or of calcareous carbonate, will generally undo ſuch alteration, and reſtore the original colour, by decompoſing and neutralizing the acid or oxygene which had cauſed the alteration. Of this hundreds of inſtances might be given, it being the caſe of almoſt all vegetable or animal colouring matters; it will however be ſufficient to mention, what moſt people have ſeen, that ink, dropped into a glaſs of diluted nitric, vitriolic, or other acid, will loſe its colour, and that it may be again reſtored by adding a ſuitable portion of vegetable or foſſil alkali; and that this may be done ſeveral times with the ſame ink, and therefore the change, or loſs of colour, could not have been the effect of combuſtion. If however this ink had been fixed, by dying in the ſubſtance either of wool, ſilk, linen, or cotton, and the ſubſtance ſo dyed had been dipped into a glaſs of diluted acid, as before mentioned, a conſiderable part of the colouring matter would have been diſlodged, and ſeparated from the dyed ſubſtance, by its affinity with the oxygene or acid; and though no combuſtion had taken place, the colour ſo ſeparated and loſt, could not be again reſtored without a ſecond dying: and this loſs of colour would be ſimilar to what frequently happens to colours from expoſure to ſun and air, by which they are gradually weakened, many of them without any other change of tint than the ſimple diminution of their original body, or quantity of colouring matter; and this continuing in the more fugitive colours, particularly that of turmeric, the cloth is ſoon left as white as before it had been dyed, without any thing like combuſtion having ever taken place in

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it, or in the matter with which it was dyed [8]. Mr. Sennebier expofed a great variety of woods to the action of the fun and air, and found all their colours very foon affected. The white woods were generally made brown, and the red and violet changed either to yellow or black. Guaiacum was rendered green; the oak and the cedar were whitened, as were the brown woods generally; effects which certainly do not refemble thofe of combuftion, any more than the bleaching of wax and tallow by expofure to air.

The colour of each particular fubftance evidently depends on its peculiar conftitution, producing in it a particular affinity or attraction for certain rays of light, and a difpofition to reflect or tranfmit certain other rays; and in this refpect it may doubtlefs fuffer very confiderable

[8] That colours are not generally impaired by any thing like combuftion, as Mr. Berthollet fuppofes, may be prefumed from this fact—that there are but few of them, which the common muriatic acid does not injure as much as either the nitric or the fulphuric; and as there can be no combuftion without oxygene, and as the common muriatic acid either contains none (which is Mr. Berthollet's opinion), or what it does contain is confeffedly combined with it, by an affinity too powerful to be overcome by any known fubftance or means, it neceffarily follows, that the oxygene (if it contains any) cannot be liberated fo as to act in the way of combuftion upon any other matter; and therefore when the common muriatic acid changes or deftroys the colours in queftion, it changes or deftroys the affinities upon which they depend, by producing effects different from thofe of combuftion; and as the changes which it produces on colours are in moft cafes fimilar to thofe produced by the nitric, fulphuric, and other acids known to contain oxygene, it feems reafonable to conclude that thefe alfo act upon colours, by producing other effects than thofe of combuftion.

changes from the action or combination of oxygene, without any effects similar to those of combustion. And indeed the changes of colour which arise from the access of vital or atmospheric air, seldom resemble those which the mere predominence of blackness (the supposed natural colour of charcoal) would produce; though this may have been the case with the colouring matter of brown or unbleached linen, upon which Mr. Berthollet's experiments were principally made.

But whether the action of vital air, or its basis, in promoting the decays of colours, ought to be denominated a combustion or not, I am confident that, at least, some of them are liable to be impaired, not so much by an accession of oxygene, as by the loss of it; an effect, of which I have already enumerated several examples, among animal and vegetable, as well as mineral substances, deriving their colours from a combination with certain portions of oxygene; and to these I might add several other examples.

Hook and Lower long since noticed the difference of colour in arterial and venal blood; and it has been since proved, by numerous experiments, that the fine vermilion colour of the former, is produced solely by vital air, which it is capable of acquiring even through bladders, the coats of blood vessels, &c. And very recently, Mr. Hassenfratz seems to have proved (see Ann. de Chymic. tom. ix.), that as this fine red colour is gained by a dissolution of oxygene in the arterial blood, so it is lost, and the dark colour of the venal blood restored, by a

separation

ſeparation of the oxygene, in conſequence of its forming a new combination with the hydrogene and carbone thereof.

That the blue colour of indigo abſolutely depends upon a certain portion of oxygene, has been already mentioned, and I ſhall hereafter give ſome curious illuſtrations of this fact, from which it will appear that a ſolution of indigo, by loſing its oxygene, may become as pellucid, and, excepting a very ſlight yellowiſh tinge, as colourleſs as water, and afterwards ſpeedily return through all the ſhades of yellow and green to its original deep blue, by expoſure to atmoſpheric or vital air. Similar to this is the fact long ſince obſerved by the Abbe Nollet, of the tincture of archil-orchella employed to colour the ſpirit of wine uſed in thermometers, and which after ſome time loſes its colour, but ſoon recovers it again upon being expoſed to atmoſpheric air. And this alſo happens to the infuſion of turnſol, and to ſyrup of violets, which both loſe their colours when ſecluded from air, and regain them when placed in contact with it. Many other examples of the like effects might be mentioned here; but to avoid repetitions, I beg leave to refer my readers to ſubſequent parts of this work, in which I ſhall have occaſion to inſtance various animal and vegetable colours, produced ſolely by the contact of vital or atmoſpheric air; and ſome others, which, when given by dying or callico printing to wool, ſilk, cotton, &c. though unable to ſuſtain a ſingle day's expoſure to the ſun and air without manifeſt injury, were found to receive none from the action of ſtrong nitric or ſulphuric acids, but, on the contrary,

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were preferved by being wetted with them, and even with oxygenated muriatic, and fulphuric acids. But the fame colours, if covered with lintfeed oil, were found to decay more quickly from expofure to the fun and air, than if uncovered. Thefe colours therefore could not owe their decays to the contact or combination of oxygene, becaufe they were not only unhurt, but benefited by its concentrated powers in the nitric, the oxygenated muriatic, and fulphuric acids; and alfo becaufe they were fooneft impaired when defended from the accefs of oxygene, by being covered with lintfeed oil. Probably the decays of thefe colours were occafioned by a lofs of at leaft fome part of the oxygene which was neceffary to their exiftence, and which the lintfeed oil affifted in depriving them of, by its known affinity with vital air.

In forming fyftems, we are apt to draw general conclufions from only a partial knowledge or view of facts. And this even Mr. Berthollet feems to have done, not only in afcribing the decays of vegetable and animal colours, exclufively to effects fimilar to thofe of combuftion, but alfo in reprefenting the oxygenated muriatic acid as an accurate teft or meafure for anticipating, in a few minutes, the changes which thefe colours are liable to fuffer, by long expofure to the action of fun and air; for though it doubtlefs is true that the oxygenated muriatic acid, in weakening or deftroying colours, gives up to them more or lefs of the oxygene, which it had received by diftillation from manganefe; and that, by this new combination of oxygene, thofe affinities for particular rays of light, upon which their

their colours depend, are liable to be deſtroyed; it is nevertheleſs true, that the changes of colour ſo produced are no certain indication of thoſe which the combined influence of light and air will occaſion upon colours in general; there being, as I have already obſerved, and as I ſhall more fully explain hereafter, ſeveral colours which are very ſpeedily deſtroyed by the latter of theſe cauſes, though they reſiſt the ſtrongeſt action of the oxygenated muriatic acid, without any kind of injury.

Mr. Berthollet well knows, ſince nobody has contributed more to aſcertain, how much the properties of oxygene are diverſified by each particular baſis to which it unites; and it does not therefore ſeem warrantable to imagine that its action will not be modified by a baſis ſo powerful as that of the common muriatic acid, or that the united properties of both ſhould repreſent or reſemble thoſe of atmoſpheric air upon colours any more than they do in the lungs by reſpiration, where, inſtead of ſupporting life, they would inſtantly deſtroy it.

To aſcertain, by well-directed experiments made upon each particular ingredient of the materia tinctoria, in what ways, or by what changes, the colours of each are liable to be injured, would doubtleſs contribute moſt eſſentially towards perfecting the art of dying; ſince it would not only help us to diſcover more clearly by what properties each is fitted to abſorb or combine with particular rays of light, and reflect others, but alſo through what particular defects ſome are more fugitive than others: and having made thefe difcoveries, we might probably be led to the proper means of obviating or correcting fuch defects, fo as to render fugitive colours permanent, and improve thofe which are already confidered as fuch.

Under this perfuafion I lately projected various experiments upon the colours of different dying drugs, calculated to afcertain the effects of light upon them, *in vacuo*, as well as when furrounded or covered by the feveral kinds of air, or by water, or alkohol, or the different acids, oils, or varnifhes, both in warm and in frofty weather; and alfo the effects of the like agents and circumftances upon the fame colours, placed in obfcurity; meaning, as far as might confift with the prefent ftate of chymical knowledge, and the defects of our fenfes, inftruments and means when applied to fuch intricate and minute fubjects, to difcover what each colour had either loft or gained by the influence or contact of thefe feveral agents, and the changes of colour refulting in every inftance from fuch lofs or gain; and flattering myfelf with the hope of being able in thefe ways to contribute greatly towards improving the knowledge and philofophy of colours. But having been called abroad during that part of laft Summer which was moft fuitable to the greateft part of thefe experiments, I have found it neceffary to defer moft of them to the next favourable feafon, when they will be undertaken and profecuted with as much care and expedition as may be compatible with my other unavoidable avocations; and an account of their refults will be publifhed in fome of the fubfequent volumes of this work. The fubject

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is, however, ſufficiently extenſive and important to merit the attention and exerciſe the talents of abler philoſophers.

But until further diſcoveries ſhall have been made, we are only authoriſed to conclude, that the permanent colours of natural bodies do not depend upon their thickneſſes, ſizes, or the denſities of their ſeveral parts or particles, but upon certain affinities or attractions (chymical or phyſical) by which they are diſpoſed to abſorb and conceal ſome of the rays of light, and to reflect or tranſmit other rays, giving the ſenſations or perceptions of their reſpective colours; that the contact of light greatly contributes towards producing theſe affinities or attractions: but it only does this (as far as we yet know) either by promoting a combination or a ſeparation of the baſis of vital air in the different coloured or colouring ſubſtances. But though moſt of the changes of colour, in permanently coloured bodies, evidently depend on changes in their reſpective portions of oxygene, I am far from thinking that this cauſe operates excluſively in all caſes, or that chymical knowledge is yet far enough advanced to juſtify even an attempt towards a complete hypotheſis reſpecting theſe moſt abſtruſe and moſt intereſting phænomena.

Should any one aſk how oxygene acts in producing theſe affinities or attractions for particular rays of light, I ſhall only anſwer with M. de Buffon, that they who require the reaſon of a *general effect*, do not conſider either the infinite extent of Nature's operations, or the narrow limits of human underſtanding.

## CHAP. II.

### *Of the Compoſition and Structure of the Fibres of Wool, Silk, Cotton, Linen, &c.*

" Ubi natura deſinit nobis incipiendum."

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BEFORE I treat of the communication or production of colours by dying or callico printing, it will be proper to inquire concerning the particular natures and differences of wool, hair, ſilk, cotton, linen, and hemp, upon which theſe operations are uſually performed. The three firſt are animal, the three laſt vegetable ſubſtances, differing from each other in their conſtituent parts and chymical properties, as well as in ſtructure and organization. Mr. Berthollet has done much towards aſcertaining the chymical differences and properties of theſe matters; and the former has been found, by his experiments, to contain a large proportion of azote (of which the latter poſſeſs but very little), and alſo a much larger proportion of hydrogene, than what belongs to vegetable matters: and as the azote and hydrogene readily aſſume an elaſtic form, the wool, hair, and ſilk, in which they abound, have leſs adheſion between their conſtituent parts, or molecules, than what exiſts between thoſe of cotton, linen, and hemp, and are therefore more ſtrongly diſpoſed, than the latter, to combine with other ſubſtances, when brought into contact with them; and it is probably in conſequence of this diſpoſition that wool, hair, and

and ſilk, manifeſt ſtronger affinities or attractions for colouring matters generally, than cotton, linen, or hemp[1]. They are alſo more readily decompoſed, or injured by acids, alkalies, and other chymical agents, which ought therefore to be more ſparingly uſed in the dying of animal, than of vegetable ſubſtances: it being found that the ſulphuric, nitric, and even the muriatic acids decompoſe wool, hair, and ſilk (by ſeparating either their azote or their hydrogene, or both in ſome caſes), and at the ſame time deſtroy, or greatly weaken the texture and connexion of their ſeveral fibres; and that alkalies prove equally injurious, by combining with them: though ſilk is indeed not ſo liable to be acted upon in theſe ways, becauſe it partakes in ſome degree of the vegetable nature.

It is from the ſuperior chymical affinities, or attractions exiſting in wool, hair, and ſilk, for colouring matters, that the facilities with which theſe ſubſtances receive, and permanently retain colours, principally reſult; though ſomething is doubtleſs to be aſcribed to the differences of conformation exiſting between their fibres and

[1] *e. g.* Cotton and linen will neither of them receive any colour by the ſame preparation, and in the ſame liquor, which dyes wool or woollen cloth ſcarlet. This is every day ſeen by the cotton edges of long ells, &c. which remain white after the reſt of the cloth is become ſcarlet. M. Dufay even cauſed a piece of cloth to be manufactured, of which the chain was wool, and the woof cotton. This was afterwards fulled, that both might be brought into a ſimilar ſtate of preparation; and the cloth being then dyed by the uſual proceſs, the woollen threads contained in it received a good ſcarlet, whilſt the cotton remained white.

those of cotton, linen, and hemp, which I shall notice under their several heads. And,

## I. *Of Wool.*

The value of this substance, and its fitness for the different kinds of manufacture, depend on the length and fineness of its fibres; of which ample information may be found in a Memoir written by M. d'Aubenton, and printed among those of the Royal Academy of Sciences for the year 1779. The business of spinning, and that of weaving, do not properly fall under my consideration; but the operation of fulling deserves to be noticed, as being connected with circumstances which seem to have some influence in the dying of wool and cloth. Fulling, according to Sir William Petty (See Spratt's History of the Royal Society), "is making the cloth to become thicker, with the diminution of its other dimensions, and the covering of its threads, so as that the cloth shall seem to be translated from the likeness of a tela (all of whose threads appear) to that of a hat which has no threads at all; for, by the way, the making of a hat (continues he) is the making of a tela, without spinning or weaving, by a kind of fulling." "This thickening," adds he, "is made by the shortening of threads; this shortening of threads by twisting of them; this twisting by the heat of the mill (for such effect visibly hath heat on hair, &c.); this heat of the mill is excited rather by an unequal motion, than by fire and scalding water, as in hats; and the constriction is furthered by oatmeal, earth, and urine, which are less potent than

than the aſtringent powders and liquors uſed about hats."

M. Monge has, however, lately given a better account of operations of felting and fulling (ſee Ann. de Chymie, tom. vi. p. 300, &c.), by which it appears, that the "ſhortening of threads" is not the effect of heat, or of any aſtringent power whatever, but an effect reſulting from the external conformation of the fibres of wool, furr, &c. which appear to be formed, either of ſmall lamina placed over each other, in a ſlanting direction, from the root towards the end or point of each fibre, like the ſcales of fiſh, lying one over the other, in ſucceſſion, from the head to the tail; or of zones, placed one upon another, as in the horns of animals; from which ſtructure each fibre, if drawn from its root towards the point, will paſs ſmoothly through the fingers; but if it be drawn in a contrary direction, from the point towards the root, a ſenſible reſiſtance, and tremulous motion will be felt by the fingers. This conformation diſpoſes the fibres of wool to catch hold of each other, and as they cannot recede, when acted upon by other bodies, they naturally advance, by a progreſſive motion, towards, and beſide each other, from the end towards the root; a diſpoſition which is very inconvenient to ſpinning, and therefore the wool is greaſed, that the aſperities ariſing from this ſtructure of its fibres may be thereby covered, or ſheathed, as a covering of oil ſheaths thoſe of a fine file. But the wool being manufactured, and the greaſe no longer uſeful, it is removed by ſcowering, not only for the ſake of cleanlineſs, but that it may

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not fruftrate the procefs of dying. The cloth is therefore carried to the fulling mill, and there fubjected to the action of large beetles, with fullers earth and water, by which the cloth is not only fcowered, but its fibres, in confequence of the ftructure juft defcribed, being made to conjoin, and advance toward, and befide each other, become fhorter, and more clofely connected, or felted together, the warp and woof lofing in extent, but gaining proportionably in thicknefs.

The lamina, or zones, under confideration, afford many interftices in the fibres of wool, fuited to receive and contain the particles of colouring matters, when applied to them in the operation of dying; but thefe interftices being fmall, and the fibres of the wool naturally elaftic, no colour can be conveyed into thefe cavities, until they are diluted by hot or boiling water; whereas filk, cotton, and linen, are made to receive colours without heat, as permanently as with it. And this difference manifeftly arifes from the fmallnefs of the interftices in which the colouring particles are depofited in wool, and the elafticity of its fibres, which make it neceffary to dilate them by hot or boiling water; and as the colouring particles are only made to enter and depofit themfelves by an artificial dilatation, it follows that, when this ceafes, the filaments will again contract to their former fize, upon the colouring matters fo introduced, and hold them much more ftrongly than they are likely to be held in other fubftances whofe interftices are large enough to receive colouring particles without being dilated, and which, therefore, cannot be ſuppoſed ever to contract and compreſs them in the ſame way: and this difference, joined to the ſuperiour chymical attraction of animal fibres for colouring matters, will ſufficiently explain why many colours dyed upon wool and hairs, prove ſo much more durable than upon cotton or linen. Wool is naturally covered with a kind of oil, which would obſtruct the proceſs of dying, and is therefore to be removed, by what is called ſcowering; an operation ſufficiently known. Wool, when dyed in the fleece, takes up much more colouring matter than when ſpun, and much more than when wove into cloth. It is alſo more or leſs penetrated, according to the fineneſs of its own texture, and the particular nature of the colouring matter with which it is dyed. The very coarſe wool taken from the thighs and tails of ſome rams and ſheep, being never made to receive colours without difficulty; and indeed the very fineſt cloth is never thoroughly dyed ſcarlet, it being always found white within when cut.

Wool taken from different breeds of ſheep, in various countries, is naturally of different colours; as white, yellow, reddiſh, and black. Formerly all the flocks in Spain, excepting thoſe of Andaluſia, were of this laſt colour, it having been preferred for wearing by the native Spaniards; and this natural browniſh black is even at this time manufactured, and worn conſtantly by ſome religious orders in Roman Catholic countries. The white wool, however, is now almoſt univerſally preferred to every other, as being ſuſceptible of receiving better colours by dying,

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than any of thofe which are natural. Manufactures of wool, though fuperfluous to man in a ftate of nature, feem to be, of all others, the moft important in civilized fociety.

## II. *Of Silk.*

The phalena, bombyx, or filk-worm, feems firft to have become an object of human care and attention in China, where it fubfifted naturally from the earlieft times. According to the annals of that country, the wife of the emperor Hoang-Ti firft occupied herfelf in collecting the cocons which were found on trees, and in winding off their filk, which was afterwards brought into ufe.

Another fpecies of this infect is alfo found in China (the phalena atlas of Linnæus); its cocons are faid to be larger, and their filk much ftronger, than thofe of the other; but being difficult to wind, it is commonly fpun.

From China, filk was carried firft to Hindoftan, and afterwards to Perfia; but it does not feem to have been known in Greece or Rome until about the time of Auguftus, when its nature and origin being but little underftood, very confufed ideas were entertained of it; and during feveral ages it was fo fcarce, as only to be bought by, at leaft, its weight in gold; and hence the emperor Aurelian, as is related, refufed the preffing folicitations of the emprefs for a robe of filk, alleging that it would prove too coftly. In the year 555, however, two monks came from India to Conftantinople, bringing with them a confiderable number of filk-worms, and inftructions for their management and propagation, as well as for collecting, winding, and manufacturing their filk; in confequence of which, eftablifhments were formed at Athens, Corinth, and Thebes, for profiting by this acquifition; and about the year 1130, Roger king of Sicily, returning from his crufade to the Holy Land, brought with him, from Athens and Corinth, feveral prifoners acquainted with the manufacture of filk, and management of filk-worms; and to avail himfelf of their knowledge in thefe refpects, he caufed fuitable manufactories to be eftablifhed for them at Palermo and Calabria, and his example was foon followed in other parts of Italy, as well as in Spain; and it was attempted to be followed in England afterwards by James the Firft, who repeatedly urged the planting of mulberry trees, and the propagation of filk-worms, in the ftrongeft terms to his fubjects, though with but very little fuccefs.

The fibres of filk are naturally covered with a kind of varnifh, or gummy fubftance; and almoft the whole of what we know in Europe, is moreover tinged of a yellow colour, which it is neceffary to remove, as well as the varnifh, for moft of the purpofes to which filk is applied. This is commonly done by fubmitting it to the action of foap, in circumftances which are already fufficiently known, and which Mr. Berthollet has fo fully defcribed, as well as fome other means for anfwering this double purpofe, that I fhall add nothing more on this fubject.

When ſilk has been freed from both its gummy varniſh and its yellow colour, it is ſometimes neceſſary to whiten it ſtill farther, by the fumes of ſulphur applied to it, and confined in a ſtove. But though ſulphureous acid gas, applied in this way, readily whitens the ſilk, and thereby renders it more fit to exhibit lively colours, a portion of ſulphur adheres to it, which muſt be removed by ſoaking and agitation, for a conſiderable time, in warm water, that it may not tarniſh the colours intended to be given by dying; an effect which ſulphur generally produces, both to thoſe of wool and ſilk. The luſtre ſo much deſired in colours dyed upon ſilk, ſeems, in a great degree, to reſult from the gloſs and poliſh of its ſurface, which acids, alkalies, and other chymical agents (particularly the ſolutions or oxyds of tin), contribute to impair, and are therefore to be ſparingly uſed.

Silk, in its diſpoſition to receive and retain colours for dying, ſeems to partake of a middle nature between that of the animal and vegetable ſubſtances: by its abundance of azote and hydrogene, it poſſeſſes, like wool, a ſtrong attraction for colouring matters; but its fibres having neither a ſimilar organization, nor an equal degree of elaſticity, it is capable of imbibing colours, like linen and cotton, without any previous dilatation of its pores by hot water, but, like them, it parts with the colours ſo imbibed the more eaſily, in conſequence of this natural openneſs, or the want of contraction, in its pores; though, upon the whole, colours dyed in ſilk are more laſting than when dyed in linen and

and cotton, on account of its greater affinity with colouring matters, refulting from its animal nature.

In the year 1709, Mr. Bon, Firft Prefident of the Chambre de Comptes at Montpellier, communicated, to the Royal Society of that city, a difcovery which he had made of a new kind of filk, from the very fine threads with which feveral fpecies of fpiders entwine their eggs; which threads were found to be much ftronger than thofe compofing the fpider's web. They were eafily feparated, carded, and fpun, and then afforded a much finer and ftronger thread than that of the common filk, though fomewhat lefs gloffy. They were alfo found capable of receiving all the different dyes with equal facility. Three ounces of this new filk made a pair of durable ftockings of the largeft fize; and as the fpiders were much more prolific, and much more hardy than the filk-worms, great expectations were formed of benefit from this difcovery. M. Reaumur therefore took up, and profecuted the inquiry with zeal. He conceived that, when fpiders were artificially multiplied for the production of filk, it would be impoffible to provide them fufficiently with flies, their natural food. This, however, was foon removed, by his finding that they would fubfift very well upon earth worms chopped, and upon the foft ends or roots of feathers. But a new obftacle arofe from their unfocial propenfities, and proved unfurmountable; for though at firft they feemed to feed quietly, and even work together, feveral of them at the fame web, yet they foon began to quarrel, and the ftrongeft devoured the weakeſt, ſo that of two or three hundred, placed together in a box, but three or four remained alive after a few days; and nobody could propoſe to keep and feed each ſeparately. M. Reaumur found their ſilk to be naturally of different colours; particularly white, yellow, ſky blue, grey, and coffee-coloured brown. See Hiſt. & Mem. de l'Acad. Royale des Sciences, ann. 1710.

## III. *Of Cotton.*

The genus of cotton-bearing vegetables (*Goſſypium*, Linn.) conſiſts of ſeveral ſpecies, and a multitude of varieties, moſt of which are herbaceous annual plants; but ſome are perennial ſhrubs or trees; they differ alſo from each other in the length, fineneſs, ſoftneſs, flexibility, and colours of the cotton which they ſeverally produce. The climate is moreover ſuppoſed to have conſiderable influence on the texture and quality of the different ſpecies of cotton; that which grows neareſt the equator being generally the moſt eſteemed. There are two ſpecies which ſeem to have belonged originally to Siam; the firſt is white, and of a long fine ſtaple, capable of being ſpun into very fine threads: this ſpecies has been tranſplanted to the Weſt Indies a conſiderable time; the other is naturally of that browniſh buff colour which it retains in the pieces of cloth manufactured from it, and denominated *nankins*. The ſhrub on which it grows has been lately introduced at Jamaica, and, I believe, at the Bahama Iſlands. But a more remarkable ſpecies of cotton, naturally of a crimſon colour in the pod, has been mentioned by different travellers as growing in Africa,

Africa, and principally in the Eyeo country. Mr. Clarkſon informs us, that a ſmall ſpecimen of it was brought home (to Great Britain) in the year 1786. He adds, that "the value of this cotton would be great both to the importer, and the manufacturer of muſlins: the former would immediately receive eight ſhillings for a pound of it, and the latter would gain conſiderably more by his ingenuity and taſte." The cottons of Cyprus, and other parts of the Levant, are generally whiter, and their filaments more dry and elaſtic, than thoſe of other countries; and theſe peculiarities have been ſuppoſed to render the former particularly ſuited to reflect, and permanently retain what is called the Turkey red.

The manufacture of cotton has lately become one of the moſt important in Great Britain. It was computed that twenty millions of pounds weight of unmanufactured cotton were imported into Great Britain in the year 1786.

The ſtructure of the fibres of cotton has not been well aſcertained. Lewenhoeck, by microſcopical examinations, found each of them to have two ſharp ſides; and it ſeems to be owing to this circumſtance, or to their poſſeſſing ſome aſperities like the filaments of wool, that cotton greatly irritates and inflames wounds, ulcers, &c. if applied to them inſtead of lint, from which they differ totally in this reſpect; and perhaps the particular ſtructure which occaſions this difference, alſo occaſions ſome in the conformation and number of their pores, to which alone can be aſcribed the diſpoſition which cotton manifefts to admit and retain colours better than linen, though not fo well as wool and filk, becaufe its vegetable nature does not afford it equal attraction for colouring matters.

M. le Pileur d'Apligny endeavoured to explain the caufe why colours are lefs durable when dyed in filk, cotton, and linen, than in wool, by fuppofing that the pores of the three firft of thefe fubftances were fmaller than thofe of wool; and that therefore colouring particles could not enter into them fo eafily and freely as into thofe of wool. But the very reverfe of this fuppofition feems true, there being little difficulty in making filk, cotton, or linen imbibe colours, even when topically applied cold, without any artificial dilatation of their pores, which is neceffary in the dying of wool. The real difficulty, therefore, is not in making them imbibe, but in making them retain the colouring particles when imbibed; becaufe, being admitted fo readily into their undilated pores, they cannot be afterwards compreffed and held therein by any contraction of thefe pores, as is done in thofe of wool. We know that it requires twice as much cochineal to produce a crimfon on filk, as on wool; which is a proof that it can take up a greater quantity, and confequently that its pores are at leaft fufficiently large and acceffible: we know alfo, that unbleached cotton is always preferred for dying the Turkey red, it being found to retain the colour moft permanently; doubtlefs becaufe its pores or interftices are lefs open before than after the operation of bleaching. This is alfo the cafe of raw or unfcoured filk, which, as the ingenious Mr. Henry of

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Manchefter obferves, is " more eafily and permanently dyed than that which has paffed the above defcribed procefs" of whitening and fcouring: and indeed the opennefs of the pores of cotton and linen, and their confequent readinefs to imbibe, both colouring particles, and the earthy or metallic bafes employed to fix moft of them, are circumftances upon which the art of callico printing is in a great degree founded. To prepare and difpofe cotton for receiving colours by dying or callico printing, it is ufually boiled in water, with a portion of vegetable or foffil alkali, for about two hours, and afterwards rinced in clean water; or it may be foaked in water, acidulated with about one fiftieth of its weight of fulphuric acid, and afterwards rinced thoroughly in a clear ftream of water.

Mr. Berthollet has fo well treated of the preparation of flax, and its converfion into linen; and this, as a fubject of dying, fo nearly agrees with cotton, excepting the circumftances already noticed, that I need offer nothing more refpecting it.

## CHAP. III.

*Of the different Kinds and Properties of colouring Matter, employed in Dying, Callico Printing, &c.*

"Toutes les chofes vifibles fe diftinguent ou fe rendent "defirable par la couleur."

COLBERT. *Inftruction general pour la Teinture, &c.*

BY colouring matter, I underftand a fubftance which poffeffes or acquires a power of acting upon the rays of light, fo as either to abforb them all, and produce the fenfation of black; or only to abforb particular rays, and tranfmit or reflect the others, and thereby produce the perception of that particular colour which belongs to the ray fo tranfmitted or reflected.

Among minerals, the colouring matter of each is diftributed equally to all its parts; but in animal and in vegetable fubftances, it generally exifts in particular parts, or particles which are capable of being extracted for the purpofes of dying, &c.

Colouring matters poffefs peculiar chymical properties, which diftinguifh them from all other kinds of matter; for befides their feveral affinities with particular rays of light, they have others which render them fufceptible of being acted upon, and modified by a variety of chymical agents, as well as of forming permanent combinations with the filaments of wool, filk, cotton, linen, &c. But in refpect of thefe affinities,

nities, colouring matters alſo differ eſſentially from each other, and muſt therefore be applied in different ways, and with very different means, to produce permanent colours in other matters. The art of dying is founded upon a knowledge of the particular properties and affinities of theſe matters, not only as far as they relate to the ſubſtances intended to be dyed, but alſo as far as they are connected with the operations of other agents, by which they are liable to be acted upon either during the proceſs of dying, or afterwards.

Many ſpecies of animal and vegetable colouring matters ſuffer nearly ſimilar changes from the action of acids, alkalies, and other chymical agents; from which it may be preſumed, that there is ſomething of a common or ſimilar nature in the conſtitution of many of them. But though it would be highly uſeful to eſtabliſh general principles and concluſions on this ſubject, we are not yet furniſhed with the neceſſary facts; and whilſt this continues to be the caſe, it will be beſt to wait, or rather ſeek for more knowledge, and avoid fallacious ſuppoſitions or explanations.

Sir Iſaac Newton ſuppoſed coloured matters to reflect the rays of light; ſome bodies reflecting the more, others the leſs refrangible rays moſt copiouſly; and this he conceived to be the true, and the only reaſon of their colours. Mr. Delaval, however, has lately maintained (ſee 2d vol. of the Memoirs of the Philoſophical and Literary Society of Mancheſter), " that, in tranſparent coloured ſubſtances, the colouring matter does not reflect any light; and that when,

when, by intercepting the light which was tranſmitted, it is hindered from paſſing through ſubſtances, they do not vary from their former colour to any other colour, but become entirely black:" and he inſtances a conſiderable number of coloured liquors, none of them endued with reflective powers, which, when ſeen by *tranſmitted* light, appeared ſeverally in their true colours; but all of them, when ſeen by *incident* light, appeared black: which is alſo the caſe of black cherries, black currants, black berries, &c. the juices of which appear red when ſpread on a white ground, or otherwiſe viewed by tranſmitted, inſtead of incident light; and he concludes, that bleached linen, &c. "when dyed or painted with vegetable colours, do not differ in their manner of acting on the rays of light, from natural vegetable bodies; both yielding their colours by tranſmitting through the tranſparent coloured matter the light which is reflected from the white ground:" it being apparent, from different experiments, "that no reflective power reſides in any of their component parts, except in their white matter only," and that "tranſparent coloured ſubſtances, placed in ſituations by which the tranſmiſſion of light through them is intercepted, exhibit no colour, but become entirely black."

"The art of dying, therefore (according to Mr. Delaval), conſiſts principally in covering white ſubſtances, from which light is ſtrongly reflected, with tranſparent coloured media, which, according to their ſeveral colours, tranſmit more or leſs copiouſly the ſeveral rays reflected from the white ſubſtances," ſince "the

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tranſparent media themſelves reflect no light; and it is evident that if they yielded their colours by reflecting, inſtead of tranſmitting the rays, the whiteneſs, or colour of the ground on which they are applied, would not in any wiſe alter or affect the colours which they exhibit."

Having had reaſon to differ from Mr. Delaval on ſome other points, I am happy in being able to agree with him on this, ſo far as relates to tranſparent colouring matters, when applied to wool, ſilk, &c. without the interpoſition of any earthy or metallic baſis. But when any ſuch opake baſis is interpoſed, the reflection is doubtleſs made by it, rather than by the ſubſtance of the dyed wool, ſilk, &c. and more eſpecially when ſuch baſis conſiſts of the white earth of alum, or the white oxyd of tin; which by their ſtrong reflective powers greatly augment the luſtre of colours. There are, moreover, ſome opake colouring matters, particularly the acetous, and other ſolutions of iron, uſed to ſtain linen, cotton, &c. which muſt neceſſarily themſelves reflect, inſtead of tranſmitting the light by which their colours are made perceptible.

It has been already mentioned, that when the rays of light are ſeparated from each other by the priſm, in conſequence of their different degrees of refrangibility, they produce a perception of ſeven diſtinct colours, with all their intermediate ſhades; and that theſe are all equally ſimple and primitive. There is, however, this peculiar property belonging to the red, yellow, and blue colours, whether priſmatic or permanent; that they are incapable of being produced, like

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all the reft, by the combination of any other colours. Blue and red will compofe a purple; blue and yellow, a green; red and yellow, an orange, &c.; but none of thefe, by any compofition, will produce either the blue, yellow, or red: thefe laft, therefore, are in all cafes fimple or uncompounded; but all the others may be, and in reality are, fometimes fimple and fometimes compounded; not only thofe which are merely prifmatic colours, but thofe which exift naturally in bodies, or are communicated by painting, dying, &c. Iron, as has been already mentioned, will, by different degrees of oxydation, produce all poffible varieties of colour; and thefe colours will be all fimple or uncompounded; and fo will the purple of gold, the green of copper, and the other colours found in the feveral oxyds of metals. This is alfo the cafe of the violet and purple dyed from logwood; of the green colouring matter of the leaves, &c. of vegetables; of the green inner bark of elder, the green juice of the berries of the rhamnus catharticus, &c.; and of the orange dyed from the quercitron bark, as will be hereafter mentioned. And among animal colours, numerous inftances may be alleged of fimple or uncompounded greens, oranges, purples, and violets: even the yellowifh white liquor of the purpura, murex, and buccinum, from which the celebrated Tyrian purple was produced, paffes quickly through all the fhades of yellow, green, violet, and purple, upon being expofed to the fun in atmofpheric air; and thefe muft neceffarily be deemed fimple, not compound colours. But on the other hand, dyers, painters, &c. daily produce orange, green, purple, and violet,

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by mixtures of the blue, yellow, and red: nor is it neceſſary that theſe ſhould be intimately mixed, ſince wool dyed of any two of theſe colours, if ſpun and wove, will uniformly appear like the ſimple homogeneous colour which, in the ſeries of priſmatic colours, lies between them. It has been repeatedly found in dying compound colours, as for inſtance, green, that laying a permanent blue over a fugitive yellow, does not defend the latter, or make it in any degree more laſting, but that it will decay (leaving the blue in full ſtrength) as rapidly as if no blue had been applied; and therefore we may preſume, that the fibres of the dyed ſtuff were but partly covered with the yellow colouring matter, and that when the blue came to be afterwards added, its particles found ſpaces ſufficient to lodge themſelves collaterally, without being placed upon the yellow particles.

Several attempts have been made to arrange and claſs the different ſpecies of colouring matters employed for dying and callico printing; but none ſeems to accord with, or give any juſt ideas of, their ſeveral natures and properties. Mr. Berthollet indeed alleges ſufficient reaſons for not dividing theſe matters, as Mr. Macquer did, into extractive and reſinous, and alſo for not making their effects depend, as Mr. Pœrner has done, upon the mucilaginous, earthy, ſaline, reſinous, or oily parts of which they were ſuppoſed to be compounded, but without propoſing any ſuitable arrangement of his own.

To me, however, colouring matters ſeem to fall naturally under two general claſſes; the firſt including

including thoſe matters which, when put into a ſtate of ſolution, may be permanently fixed, and made fully to exhibit their colours in or upon the dyed ſubſtance, without the interpoſition of any earthy or metallic baſis; and the ſecond, comprehending all thoſe matters which are incapable of being fixed, and made to diſplay their proper colours without the mediation of ſome ſuch baſis. The colours of the firſt claſs I ſhall denominate *ſubſtantive*; uſing the term in the ſame ſenſe in which it was employed by Bacon Lord Verulam, as denoting a thing ſolid by, or depending only upon, itſelf; and colours of the ſecond claſs I ſhall call *adjective*, as implying that their luſtre and permanency are acquired by adjection upon a ſuitable baſis.

Of ſubſtantive colours, I ſhall firſt notice the animal, then the vegetable, and laſtly the mineral.

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## CHAP. IV.

### *Of Subſtantive Animal Colours.*

" Tyrioque ardebat murice lana." VIRG.

THE moſt celebrated and precious of all the ancient dyes, was the purple, obtained from particular kinds of univalvular ſhell-fiſh; of which the beſt, and almoſt the only accounts, handed down to us, may be found in the writings of Ariſtotle and Pliny, and eſpecially of the latter,

latter, in whofe time the purple dye feems to have attained its greateft perfection. They, in different places, have briefly mentioned the different fhell-fifh from which the dye was obtained, how they were caught, and how their colour was prepared and applied to wool; but thefe accounts, from their brevity, were better fuited to excite, than fatisfy, an enlightened curiofity.

Pliny, in the 36th chapter of his feventh book, ranges the different fhell-fifh, giving the purple, under two genera: the firft comprehended the fmaller fpecies, under the denomination of Buccinum; fo called from their refemblance to a hunting horn; and the fecond included thofe denominated Purpura. Thefe Fabius Columna conceives to have been alfo diftinguifhed by the generic name of Murex; though others fuppofe this to have fignified all the different fpecies generally.

Many fabulous accounts have been given of the firft difcovery of the purple liquor, and its application as a dye, which feems to have been made at Tyre, about fourteen or fifteen centuries before the Chriftian æra; and the Tyrian dye, in confequence thereof, became highly celebrated in different countries.

The feveral fpecies of fhell-fifh under confideration, were found as well on the European as the African coafts of the Mediterranean; and they appear to have given colours of different fhades; and the liquors yielding thefe colours were frequently mixed with each other, in various proportions, to produce other variations of colour: one, or at moſt two drops, of this liquor were obtained from each fiſh, by extracting and opening a little reſervoir, placed in the throat. But to avoid this trouble, the ſmalleſt ſpecies, as we are informed by Ariſtotle and Pliny, was generally bruiſed whole in a mortar; and this, according to Vitruvius, was often done with the larger; though the other fluids of the fiſh muſt have neceſſarily debaſed the colour in ſome degree. The liquor, when extracted, was mixed with a conſiderable portion of ſalt, to preſerve it from putrefaction, and was then diluted with five or ſix times as much water, and kept moderately hot, in leaden or tin veſſels, for the ſpace of ten days, during which the liquor was often ſkimmed, to ſeparate all impurities; after which the wool, being firſt well waſhed, was immerſed and kept therein for five hours, then taken out, carded, and again immerſed, and continued in the liquor until all the colour was exhauſted. To produce particular ſhades of colour, nitre, urine, and a marine plant, called Fucus, were occaſionally added. Several of theſe varieties of colour have been particularly mentioned by ancient writers. One of them, which was very dark, ſeems to have been a violet, inclining towards the reddiſh hue; "Nigrantis roſæ colore ſublucens." Plin. lib. ix. ſect. 50. Another, and leſs eſteemed, was probably a kind of crimſon; but the moſt eſteemed, and that in which the Tyrians particularly excelled, reſembled coagulated blood; "laus ei ſumma in colore ſanguinis concreti." Plin. ſect. 62. There was, moreover, a fourth kind, known in later times; an account of which may be be found in Perrault's tranſlation of Vitruvius. Pliny ſays, the Tyrians firſt dyed their wool in the liquor of the purpura, and afterwards in that of the buccinum; the purple mentioned in Exodus, chap. xxv. was alſo twice dyed. Wool which had received this double Tyrian dye (diabapha), was ſo very coſtly, that, in the reign of Auguſtus, each pound of it ſold for 1000 Roman denarii (about 36l. ſterling). But leſt this ſhould not ſufficiently exclude the uſe of it, from all who were not inveſted with the higheſt dignities, laws were made, inflicting ſevere penalties, and even that of death, under the later emperors, upon all who might preſume to wear it. The art of dying this colour came at length to be practiſed only by a few individuals, appointed and maintained by the emperors for that purpoſe; and it being interrupted about the beginning of the 12th century, all knowledge of it was ſoon after loſt, except what remained in the more ancient writings; and during ſeveral ages this celebrated dye was conſidered and lamented as an irrecoverable loſs.

It happened, however, that Mr. William Cole of Briſtol, being at Minehead about the end of the year 1683, heard, from two ladies there, of a perſon living at a ſea-port in Ireland, "who made conſiderable gain by marking, with a delicate durable crimſon colour, the fine linen of ladies and gentlemen, ſent him for that purpoſe;" and that this colour was "made by ſome liquid ſubſtance taken out of a ſhell-fiſh." Mr. Cole being a lover of natural hiſtory, and having his curioſity thus excited, went in queſt of theſe ſhell-fiſh; and after trying various kinds without

 ſucceſs,

fuccefs, he at length found confiderable quantities of the buccinum on the fea-coafts of Somerfetfhire, and the oppofite coafts of South Wales; and after many ineffectual endeavours, he at length found the colour in a " white vein, lying tranfverfely in a little furrow, or cleft, next to the head of the fifh;" which, fays he, " muft be digged out with the ftiff point of a horfe-hair pencil, made fhort and tapering, by reafon of the vifcous clamminefs of the white liquor in the vein, that fo by its ftiffnefs it may drive in the matter into the fine linen, or white filk," intended to be marked. Letters or marks made in this way, with the white liquor in queftion, " will prefently," adds he, " appear of a pleafant green colour, and if placed in the fun, will change into the following colours, *i. e.* if in the winter, about noon, if in the fummer, an hour or two after fun-rifing, and fo much before fetting (for in the heat of the day in fummer the colours will come on fo faft, that the fucceffion of each colour will fcarce be diftinguifhable;) next to the firft light green, will appear a deep green;" " and in a few minutes this will change into a full fea green; after which, in a few minutes more, it will alter into a watchet blue; from that, in a little time more, it will be of a purplifh red; after which, lying an hour or two (fuppofing the fun ftill fhining), it will be of a very deep purple red; beyond which the fun can do no more." He remarks, however, " that thefe changes are made fafter or flower, according to the degree of the fun's heat;" " but then," adds he, " the laft and moft beautiful colour, after wafhing in fcalding water and foap, will (the matter being again put out into the fun or

wind

wind to dry) be much a differing colour from all thofe mentioned, *i. e.* a fair bright crimfon, or near to the Prince's colour; which afterwards, notwithftanding there is no ftyptic to bind the colour, will continue the fame, if well ordered, as I have found in handkerchiefs that have been wafhed more than forty times; only it will be fomewhat allayed from what it was after the firft wafhing." Mr. Cole found, that, when linens marked with the white liquor in queftion were taken out of the fun, when the colours had only reached any one or more of the before mentioned fhades, and fhut up between the leaves of a book, the colour or colours made no farther progrefs whilft fo fhut up, but remained always of the fame fhade. He alfo found, that whilft linen marked with the white liquor was drying by expofure to the fun, *for the firft time*, it would always "yield a very ftrong fœtid fmell (which divers who fmelt it could not endure), as if garlick and affafœtida were mixed together;" and this happens in cafes where linen, after being marked, had been fhut up in a book for twelve months before it was expofed to the fun's rays. He alfo found, that the colour in linen which had been dried, and wafhed immediately after being marked, was better than when it had lain fourteen months between the leaves of a book, unwafhed.

Mr. Cole fent fome of the firft linen marked by him in this way, to Dr. Plot, then one of the Secretaries of the Royal Society, in November 1684; and it was foon after fhewn to King Charles the Second, who admired it greatly, and defired that fome of the fhell-fifh might be collected and brought to town, that he might see the liquor applied, and the successive changes of colour which it underwent; but before this could be done, the king died; and though Mr. Cole's letter (from which the preceding extracts were made) was in the following year published, in the fifteenth volume of the Philosophical Transactions, and excited the attention of philosophers in most of the countries of Europe, it does not appear that any attempt was made to revive the practice, along with the knowledge, of dying the ancient purple.

After an interval of twenty four years, Mr. Jussieu found a small species of buccinum, in form resembling the garden snail, on that part of the French coasts which is washed by the Atlantic ocean, and presented some of them, in the year 1709, to the Royal Academy of Sciences at Paris; and in the following year, the celebrated Mr. Reaumur found great quantities of the buccinum on the coast of Poitou; and he moreover observed, that the stones, and little sandy ridges round which these shell-fish had collected, were covered with a kind of oval "graines," some of which were white, and others of a yellowish colour; and having collected and squeezed some of these upon the sleeve of his shirt, so as to wet it with the fluid or liquor which they contained, he was agreeably surprized, in about half an hour, upon finding it stained of a fine purple colour, which he was unable to discharge by washing. This was done upon the sea-shore. He next collected a quantity of these grains, and carrying them to his apartment, bruised and squeezed different parcels

of

of them upon bits of linen; but to his great ſurprize, after waiting two or three hours, no colour appeared upon the ſpots wetted with their liquor. Unable to conceive the reaſon of this diſappointment, and having almoſt determined to return again to the ſea-ſhore, and repeat his experiment in the ſame place as before, he chanced to perceive ſome purple ſpots, occaſioned by drops of the liquor which had accidentally fallen upon a part of the plaſter with which the ſides of the window were covered, and which, having been more ſtrongly acted upon by the light, than the bits of linen wetted with the ſame liquor in the interior part of the room, had become purple, though the day was then cloudy. Without, however, perceiving this to have been the cauſe of his diſappointment, he broke off a bit of the ſame plaſter, and carrying it to the back part of the room, where the bits of linen in queſtion were laying, he wetted it with the ſame liquor, without its becoming coloured. He then thought of carrying the colourleſs bits of linen to the window, which was open, and there he ſoon perceived them to become purple. It was then faſhionable to explain all effects upon mechanical principles, as it was at the time when he alſo endeavoured to account for the ſhock of the torpedo, as reſulting *mechanically* from a very quick ſtroke given by the contraction of particular muſcles in that fiſh. Mr. Reaumur, therefore, ſoon perſuaded himſelf, and others, that the bits of linen which had remained colourleſs whilſt at the back part of his room, were rendered purple at the window by the different manner in which the air acted upon the colouring liquor in the latter; and that this difference confifted folely in the air's having greater motion at the window, than at a diftance from it; and almoft all his fubfequent experiments feem to have been calculated to confirm this hypothefis.

He placed bits of linen, juft wetted with the colouring liquor, in the open air, and laying a ftone upon each, he found the covered part remain colourlefs, whilft the reft were made purple; which he afcribes to the mechanical impreffion of wind, not confidering that the ftones kept off the light, as well as the air. Having read an account of Mr. Cole's obfervations, in the Philofophical Tranfactions, Mr. Reaumur expofed a bit of linen, wetted with the colouring liquor, to the rays of the fun, collected by a fmall burning glafs, and faw it become purple in an inftant; and confequently, without being able to diftinguifh any of the changes of colour through which it had fo rapidly paffed. Putting another bit of linen, wetted with the fame liquor, fo near to the fire that it would have burned had it been dry, he likewife faw it become purple immediately; but with equal degrees of heat, the effects produced by the fun's rays were beyond comparifon the greateft.

Mr. Reaumur conceived the grains in queftion to be the eggs or fpawn of fome fifh, but whether of the buccinum, or any other fpecies, he was uncertain; and under this uncertainty he propofed calling them " Oeufs de Pourpre," eggs of purple. The colour which they produced, was at leaft equal, if not fuperior in beauty, as well as durability, to that of the buccinum: though

though the colouring liquor of the latter was much thicker than that of the purple eggs, and not liable to paſs through the different changes of colour ſo quickly as that of the eggs, excepting when diluted. Having put ſome of this diluted liquor into two glaſſes, and placed one of them in contact with the ſun's rays, and the other near the fire, the former became purple without any ſenſible addition of heat, whilſt that which was at the fire had only began to acquire te firſt ſhade of colour though it was ſenſibly ot: and indeed he always found the colours oduced by the ſun to be more beautiful than y others; a circumſtance which he endeavours explain, by ſuppoſing its rays to act mechaically, in changing the figures or arrangements f the particles of the liquor, in the ſame way he ſuppoſed the wind to change them, but ith more efficacy. When Mr. Reaumur rerned from the ſea-coaſt to Paris, he filled two ials with the diluted liquor of the buccinum, ich he brought with him, and upon examing them at the end of his journey, he found that e of them remained colourleſs as at firſt, it ing full of the liquor; the other, however, ving been ill corked, had loſt an eighth part its contents, and had, as he ſays, acquired a le colour; which he attributes to the mechaal effects of ſhaking from the phial imperly filled.

Mr. Reaumur perceived the ſame diſagreeable ell of garlick from the liquor which Mr. Cole d before mentioned; and he found it the more upportable, as the heat of the ſun or fire was ſtrongeſt. The colour of the liquor was not produced, or affected either by vegetable alkali (carbonate of pot-ash), or sulphuric acid: but a very little corrosive sublimate, put into the diluted liquor of the buccinum, instantly rendered it blue, and the colour was soon precipitated with the mercury, to the bottom of the vessel, leaving the liquor colourless; an effect which, as usual, he endeavoured to explain mechanically, by supposing the sublimate to consist of little globules, stuck round with sharp poirs, which enabled it to change the arrangement of the particles of the liquor more expeditiou, even than he had supposed it done by the wil. He found that the liquor of the buccinum tastl as hot as the hottest pepper, whilst that of t purple eggs was saltish; but even this was viscid, that it did not run, when topically a plied to linen, &c.; and as the eggs were, cording to Mr. Reaumur's account, so plerful[1], that one man might collect half a bushef them in a few hours, there certainly is reaso think that they would be highly useful, at st in calico printing, where their liquor might be applied, with the greatest facility, both for 1ciling and printing, as a substantive topical lour, and where a small quantity would go, especially upon fine muslins. But at that the art of calico printing had never been ptised in France, and therefore nobody thot of applying Mr. Reaumur's discovery to t purpose.

About the beginning of the year 1736, Duhamel found the purpura (the buccinum

[1] See Mem. de l'Acad. Royale des Sciences, an. 1711.

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having been difcovered by Cole and Reaumur) in great abundance upon the coaft of Provence; and found it to agree very well with the defcription thereof given by Rondelet. He found the vifcid colouring liquor of the fifh to be white, except in a few inftances, where it was green, which he fufpected to be fome morbid effect. The white liquor being expofed to the fun's rays, affumed the following colours: 1. a pale green and yellow; 2. an emerald green; 3. a dark bluifh green; 4. a blue, with a beginning rednefs; and 5. a purple; and thefe all happened in lefs than five minutes. Linen wetted with the white liquor, and left all night in a dark room, had only become green in the morning; and this was alfo the cafe of linen wetted in like manner, and expofed all night in the open air, but fhaded from the moon's light. A piece of linen, wetted in the fame manner, being partly expofed to the fun's rays, and partly hid by a crown-piece of filver, the former became purple, whilft the latter was only green. Other linen fo wetted, being heated in a Dutch oven before the fire, or on a hot iron, became of a dark green, but not purple. The fumes of burning fulphur only produced a dark green; and this was moreover the cafe with the different coloured rays of the fun, applied feparately by a prifm. Wifhing to fee whether evaporation tended to colour the white liquor, Mr. Duhamel put fome of it into a phial well ftopped; and, upon expofing it to the fun, found the liquor become of a reddifh purple almoft immediately. A piece of linen wetted, and ftuck upon the back of a plate of polifhed glafs, three lines in thicknefs, and expofed to the fun's rays, became purple even

before

before it had dried. Three pieces of linen fo wetted, being covered, one with white, a fecond with black, and the third with oiled paper, the laft foon became a good purple colour, but the others only became green. Linens wetted in like manner, and expofed to the light of the moon, or of burning wood or candles, became green, but not purple. Expofure to the fun's rays always produced the purple, and moft expeditioufly, when its light and heat were ftrongeft. The fun-fhine of the month of March having proved much more efficacious than that of January or February, the purple was inftantly produced by the fun's rays, collected under a burning glafs. The liquor which Mr. Duhamel fufpected to be morbidly green, became purple fooner than the white liquor; a circumftance which does not indicate its greennefs to have been the effect of difeafe. In linens where the colour had ftopped at the green, without reaching the purple hue, it was foon carried off by boiling with foap, foffil alkali, alum, &c. which the colours that had become purple withftood for a long time, and were not hurt by the fumes of burning fulphur. See Memoirs of the Royal Academy of Sciences, &c. 1736.

Until Mr. Cole had difcovered the buccinum, no adequate conceptions could have been formed of the changes through which its liquor and that of the purpura became purple. Ariftotle and Pliny had, indeed, both given intimations of their being primitively white; and Pliny had mentioned one of the intermediate colours, the green[z]. That the other changes were not

[z] "Color aufterus in Glauco, & irafcenti fimilis mari." Lib. ix. fect. 60.

more

more diſtinctly noticed, muſt be aſcribed to the little attention then beſtowed upon ſubjects of natural philoſophy, and perhaps to a want of ſufficient communication with the purpurarii piſcatores, by whom the liquor was collected and ſalted. And there can be no doubt of the identity of the ſhell-fiſh employed by the ancients, and thoſe diſcovered by Cole, Reaumur, and Duhamel, or of the ſimilitude of changes and means by which their ſeveral liquors became purple. In a collection of Anecdota Græca, lately publiſhed by M. d'Anſe de Villoiſon, there is, as Mr. Berthollet mentions, a deſcription of the manner of catching the ſhell-fiſh, employed for the purple dye, written by an eye-witneſs, Eudocia Macrembolitiſſa, daughter of Conſtantine the eighth, who lived in the eleventh century, while the knowledge and practice of dying that colour for the uſe, and at the expence, of the Greek emperors ſtill ſubſiſted; and from which it manifeſtly appears, that in thoſe times, as well as in ours, the purple did not acquire its due luſtre and perfection until it had been expoſed to the ſun's rays.

Thoſe who are duly acquainted with the more recent chymical diſcoveries, can only heſitate between two ways of accounting for the changes through which the liquors of the purpura and buccinum become purple; I mean, whether it be by gaining oxygene from the atmoſphere, as happens when indigo acquires its blue colour; or whether it be not rather by the ſeparation of a redundant portion of oxygene, naturally combined for ſome unknown, but neceſſary purpoſe in the liquor of theſe ſhell-fiſh; and in that particular

particular ſtate which will not admit of its being ſeparated without the application and aſſiſtance of light; as is alſo the caſe of horned ſilver, rendered purple by the ſun's rays; of vegetables, rendered green by the ſame cauſe, after they had become white by growing in darkneſs; of peaches, purple grapes, and other fruit, which never acquire their proper colours by any degrees of heat, but always remain white or green if ſhaded and ſecluded from the contact of the ſun's rays. A very few experiments which I hope to have an opportunity of making hereafter, would aſcertain this point beyond the poſſibility of doubt; though in fact there is, I think, at preſent very little room to doubt but that the purple, under conſideration, is produced in the laſt of the two ways juſt mentioned.

The celebrated Fontenelle, in giving his account of Reaumur's diſcovery of the purple, began by obſerving, that not only more things were found in modern than had been loſt in ancient times, but that it was even impoſſible for any thing to be loſt unleſs mankind were willing that it ſhould remain ſo; it being only neceſſary to ſearch in the boſom of nature where nothing is annihilated; and that to be certain of the poſſibility of a thing's being found, was a conſiderable ſtep towards finding it. But before the buccinum and purpura were found by Cole, Reaumur, and Duhamel, America had been diſcovered, and new dying materials obtained from thence, ſuperior in beauty, and eſpecially in cheapneſs, to thoſe ſo highly valued in ancient times, at leaſt for wool; though it muſt be confeſſed that no other ſubſtance will afford a durable

durable ſubſtantive purple to linens or cottons, capable of being topically applied with ſo much ſimplicity and expedition; and for theſe reaſons it ſeems probable that the diſcoveries of theſe Gentlemen might ſtill be applied with advantage in ſtaining or printing fine muſlins, for which but little colouring is required. And indeed, there was a ſpecies of buccinum found about a century ago near Panama, and particularly on the coaſts of Guayaquil and Guatemala, of which conſtant uſe appears to have been made in thoſe countries for purpoſes of dying cotton. Juſſieu the elder, Thomas Gage, and others, have mentioned them; Don Antonio Ulloa, in particular, ſays, "they are ſomething larger than a nut, and contain a juice which, when expreſſed, is the true purple; for if a thread of cotton or the like be dipped into this liquor, it becomes of a moſt vivid colour, which repeated waſhings are ſo far from obliterating, that they rather improve it; nor does it fade by wearing." "This precious juice," continues he, "is extracted by different methods; ſome take the fiſh out of the ſhell, and laying in on the back of the hand preſs it with a knife from head to tail, ſeparating that part of the body into which the compreſſion has forced the juice, and throw away the reſt." This being done, "they draw threads through the liquor which is the whole proceſs; but the purple tinge does not appear immediately, the juice being at firſt of a milky colour, from which it changes to a green, and, laſtly, to this celebrated purple."

Snails, with the ſame property, exiſt in various other parts of the world. Mr. John Nieuhoff relates

relates that "*abundance* of purple ſnails are found in the iſlands over againſt Batavia." "They are boiled (adds he) and eaten by the Chineſe, who have a way of poliſhing the ſhells, and pick out of the middle of the ſnail a certain purple-coloured ſubſtance which they uſe in colouring and making red ink.

In the fiftieth volume of the Philoſophical Tranſactions, Dr. J. A. Peyſonnel, F. R. S. then reſiding at Guadelupe, deſcribes what he calls the naked ſnail producing purple, "Limax non cochleata, purpur ferens," as found in the ſeas of the Antilles, and "precious for the beautiful purple colour it produces in the ſame manner that the cuttle-fiſh produces its ink." "There is (continues he) a hollow in the back of the animal where the canal, filled with a reddiſh juice, paſſes out carrying it to a fringed body like a meſentery; and it is there the purple juice is brought to perfection." "When the animal is touched, he makes himſelf round and throws out his purple juice as the cuttle-fiſh does his ink: this juice is of a beautiful deep colour; it tinges linen, and the tincture is difficult to get out."

It is however to be remarked, that the liquor of the naked ſnail exiſts naturally of a purple colour, without the application of light; a circumſtance which denotes very different properties. In Brown's Hiſtory of Jamaica, there are deſcriptions of two ſhell-fiſhes having a ſimilar colouring liquor; one is termed "the larger dark lernea, or ſea-ſnail, frequent in the American ſeas." Dr. Brown obſerves, that "on touching

ing this creature, it emits a confiderable quantity of vifcid purple liquor, which thickens and colours water about it fo much that it can fcarcely be feen for fome time after, by which means it is generally enabled to make its efcape in times of danger." "I have gathered," adds Dr. Brown, "a fmall quantity of the difcharges of this creature, and ftained a linen handkerchief with it; it gives a very beautiful dark purple colour which is not apt to change with either acids or alkalies; but is eafily wafhed out:" a circumftance in which it totally differs from the buccinum, &c. as well as in that of liquor being naturally emitted of a purple colour. The other of thefe fhell-fifh is termed the purple ocean fhell, and upon being touched, "it diffufes a beautiful purple liquor," fays Dr. Brown, which feems to refemble the former. The fepia, or cuttle-fifh, has long been known to provide for its fafety in like manner, by difcharging in times of danger a vifcid bitter black fluid, which Rondolet feems with reafon to have confidered as its bile. It was ufed as ink by the Romans; and is faid at this time to form the bafis of Chinefe ink. I fufpect however, that neither this, nor the liquor of either Dr. Brown's fhell-fifhes, or of Dr. Peyfonnel's naked fnail, poffefs fuch properties in dying, as to merit the denomination of fubftantive colours.

Being at fea in the year 1783, on my paffage from London to Philadelphia, I caught the holuthuria phyfalis of Linneus, called the man of war, or Portugueze man of war, by Englifh feamen. Some of them are of a beautiful crimfon, though this was of a fine purple colour, and when cut open, yielded a fluid of the ſame colour, with ſome of which I ſtained the corner of a cambrick handkerchief, which was afterwards waſhed in its turn, with about two dozen more, during nine months which I paſſed in America, without having, as far as I can remember, loſt much of its colour; but ſoon after, upon my return to London, it was picked out of my pocket, before I was able thoroughly to aſcertain how far the very acid liquor of the holuthuria phyſalis would yield a permanent ſubſtantive dye.

There are ſeveral other animal matters which ſeem worthy of being tried for dying, and particularly a large green worm, infeſting the tobacco plants in North America, and which, upon being bruiſed, yields a conſiderable portion of green liquor, which indeed I have not had an opportunity of trying, ſince the idea of its probable utility in this way occurred to my mind.

Mr. Martin Liſter (ſee Philoſophical Tranſactions, vol. vi.) obſerves, that "the common hawthorn caterpillar will ſtrike a purple, or carnation, with lye, and ſtand; the heads of beetles and piſmires will, with lye, ſtrike the ſame carnation colour, and ſtand; and the amber-coloured ſcolopendra (adds he) will give, with lye, a moſt beautiful and pleaſant amethyſtine, and ſtand:" but whether he means that they will ſtand in this way, when applied to paper only, or to the ſubſtances uſually made to receive dyes, does not appear. In another part of the ſame volume, Mr. Liſter mentions an inſect (cimex), whoſe whofe eggs, bruifed upon white paper, " ftain it of themfelves, without any addition of falt, of a lively vermilion colour."

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## CHAP. V.

### *Of Vegetable Subftantive Colours.*

" Combien de tentatives n'aura t'on pas fait avant que " de parvenir au point d'appliquer convenablement " les couleurs fur les etoffes, et de leur donner " cette adherence et ce luftre qui fait le principal " merite de l'art du teinturier, un des plus agre- " ables, mais en meme temps un des plus difficiles " qu'on connoiffe!" GOQUET *de l'Origine des Lois, des Arts, et des Sciences, &c. tome premier, 4to.*

INDIGO is probably the moft ancient of all vegetable colouring matters within our knowledge, though not ufed for dying in Europe until near the middle of the fixteenth century. Pliny mentions a fubftance brought from India, and termed Indicum, which was doubtlefs indigo; though he appears to have had but very inaccurate ideas of it, and to have confidered it as the fcum, or exudation of certain reeds adhering to mud: " ab hoc maxima auctoritas Indico, ex India venit arundinem fpumæ adhærefcente limo; cum teritur nigrum, at in diluendo mixturam purpuræ cæruleique mirabilem reddit." Plinii, l. xxxv. c. vi. Diofcorides thought it a ftone.

We have no reafon to believe, that either the Greeks or Romans ever knew how to diffolve indigo, or ufe it for dying, or any purpofe but

 that

that of painting; though it undoubtedly was uſed long before, as a dye in Hindoſtan. The firſt indigo employed in this way by Europeans, was brought by the Dutch from India. A ſpecies of the plant, from which it is there extracted, was ſoon after recognized, and made uſe of for that purpoſe, by the Portugueze in Brazil, where it grew ſpontaneouſly, as it alſo did in other parts of America. Clavigero, in his Hiſtory of Mexico, mentions indigo as having been prepared, and uſed by the Mexicans, before the Spaniards arrived in that country; and he gives an account (ſuperficial indeed) of the proceſs for obtaining it. Hernandes had long before deſcribed the indigo plant as being indigenous in Mexico, and employed by its ancient inhabitants; and Ferdinand Columbus, in his Life of Chriſtopher Columbus, mentions it as one of the native plants of Hiſpaniola. Though the Abbé Raynal aſſerts, that it was tranſplanted from the Eaſt Indies to America; which can only be true of one of the ſpecies, the indigofera tinctoria Linn.

There are various ſpecies of the indigofera, or indigo plant, growing in China, Hindoſtan, Japan, Java, and Madagaſcar, as well as in America, and differing conſiderably from each other; though their ſeveral peculiarities have not been well aſcertained. Three ſpecies only of this genus are cultivated in America. The firſt, and ſmalleſt, is the indigofera tinctoria of Linnæus, which is neither ſo hardy, nor is its pulp ſo good, as that of the others; though it yields much more, and is therefore generally preferred to both. This is what the French call indigo-franc.

franc. The ſecond is the indigofera diſperma Linn. or Guatimala indigo plant, which grows much higher, is hardier, and affords a better pulp than the former. The third is the indigofera argentea, or wild indigo, called indigo bâtard by the French, which is hardier than either of the others, and yields the fineſt pulp, though the leaſt in quantity.

The indigo plant being cut at maturity, by rape hooks, a few inches above the ground, is laid by ſtrata in a ſteeper, then overlaid with boards, and covered with water; in which it is left to digeſt and ferment until the pulp is extracted. To aſcertain when this is done, or when the fermentation has riſen ſufficiently high, and continued a ſufficient time, handfuls of the plant are drawn out every five minutes; and as ſoon as the tops become both tender and pale, and the ſtronger leaves, without being tender, are found to be pale, the liquor is drawn off immediately into the beaters: doing this too ſoon would occaſion the loſs of a great part of the pulp; and ſuffering the liquor to ferment too long, would ſpoil the whole.

When the liquor is all diſcharged into the beaters, it is agitated with buckets, or by ſuitable machines, until the tincture begins to granulate, or collect into little floculæ; and to haſten this kind of granulation, or ſeparation, it has long been uſual to add clear lime water, in greater or ſmaller quantities, until the liquor, in which the *blue* floculæ are ſuſpended, becomes, in other reſpects, colourleſs. Great attention and exactneſs are neceſſary in this, as well as in the former proceſs, to render the quality of the indigo perfect; it is moreover requiſite that the lime water employed ſhould be perfectly clear, otherwiſe it will render the indigo hard, heavy, and of a greyiſh caſt.

The liquor having been ſufficiently agitated, and impregnated with lime water, is left at reſt, that the particles of the indigo may quietly fall to the bottom; and this being done, the clear water is drawn off by a tap, placed juſt above the top of the feculence or magma, which is afterwards diſcharged, by an opening below, into another receptacle, and from thence conveyed into linen bags, which are ſuſpended in order to let the water drain off; and this being done, the indigo is put into little ſquare boxes, or formed by hands, into ſmall lumps of different ſizes and figures, and afterwards dryed in the ſhade.

Indigo ſeems to conſiſt chiefly of a particular vegetable baſis, united to a large portion of oxygene, to which its colour is principally owing, and for which it has a ſtrong attraction. In the firſt operation, that of ſteeping and fermenting the plant, this baſis is not only diſſolved and extracted by the water, but a portion of pure air is abſorbed (as is the caſe in all ſimilar fermentations), ſome of which combines with the baſis of indigo, which would indeed abſorb ſo much as to become black by a kind of combuſtion, if the fermentation were not previouſly ſtopped. In the ſecond operation, by beating and agitating the liquor, a farther addition is made of oxygene, accompanied with a proportionate change of colour, through the ſeveral

ſhades

ſhades of green progreſſively to thoſe of blue; and alſo a collection of the very minute coloured particles into little diſtinct maſſes, or floculæ. This is ſomewhat analogous to the effects of churning on cream, or of violent ſhaking upon ink in a bottle, by which its colouring matter ſoon forms large granulations, and falls to the bottom, where it continues incapable of being ever afterwards re-diſſolved, or ſuſpended by the water, which it leaves perfectly clear. The addition of lime water farther promotes the ſeparation of the blue particles, by abſorbing the carbonic acid produced by the previous fermentation of the liquor, and ſtill contained in it.

At that preciſe ſtate when the indigo is of a full deep green, and before any perceptible ſeparation or collection of its coloured particles has taken place, it is, I am perſuaded, in the ſtate the beſt ſuited of all others to dye the moſt permanent, if not the moſt lively colours. The remaining parts of the proceſs ſerve only to collect the ſubſtance of the indigo into a dry ſolid form, in which it may be more conveniently preſerved, and tranſported to diſtant countries for after uſe.

I have mentioned that too much fermentation, during the firſt part of the proceſs, would produce a beginning of combuſtion, and blackneſs in the pulp of the indigo; and the like effects reſult from too much beating, or agitation in the ſecond. On the other hand, if the coloured particles were ſeparated by lime water, before they had acquired a ſufficiency of oxygene by agitation, the indigo would have a greeniſh caſt, which is carefully avoided, as it might ſeem an unfavourable circumſtance to perſons unacquainted with the true cauſe; though I am inclined to believe that ſuch indigo would, in ſome reſpects, be preferable to the other, eſpecially as it would be more eaſily brought into the ſtate of ſolution neceſſary for dying.

Indigo differs conſiderably in colour; though its differences in this reſpect may be comprehended under three general diviſions; the blue, the violet, and the copper-coloured; and each of theſe is the more pure and valuable, in proportion as it is more light: the lighteſt indigo is always blue, and ſells for the higheſt price; this is more eſpecially employed for dying Saxon blue. It is not yet known (though it has long been a deſideratum) how either the blue, the purple, or the copper-coloured indigo may always be certainly produced, at the option of the operator. I ſhall hereafter offer ſome conjectures on this circumſtance.

Of American indigo, that of Guatimala is the moſt eſteemed; but of this there are three ſorts, the copper, violet, and blue; the laſt and beſt is termed Flora by the Spaniards, and it floats on water. The indigo of Java was formerly moſt eſteemed in the Eaſt Indies; but the culture of the indigo plant having of late been greatly encouraged within the Engliſh Eaſt India Company's poſſeſſions, indigo, ſuperior even to that of Guatimala, is now brought from thence in conſiderable quantities. The whole quantity imported annually into Great Britain, conſiderably exceeds one million of pounds

weight.

weight. One English acre of rich land, by proper cultivation and management, may be made to yield five hundred pounds of indigo annually. The lighteft and beft indigo burns almoft wholly away, leaving but a very fmall portion of white afhes behind.

The fame colours, and fhades of colour, may be given by all the different kinds of indigo; which feem therefore to differ principally by containing more or fewer impurities, and confequently more or lefs colouring matter. Water diffolves the mucilaginous, and fome of the adventitious parts of indigo; of which alkohol diffolves others; but neither can diffolve any part of its colouring matter; and this is alfo true of all the alkalies, whether cauftic or aerated, and of all acids, the nitric and fulphuric excepted. There are, indeed, but two ways in which indigo, when once formed, can be diffolved: the firft of thefe is by means which attack its bafis, by fuperadding a farther portion of oxygene; the other is by fubftances which abforb and take away from indigo a confiderable part of the oxygene combined with it, fo as thereby to render its bafis liable to be acted upon, and diffolved by the pure or cauftic alkalies.

In the firft of thefe ways, fire fpeedily decompofes indigo: the nitric acid alfo, when concentrated, attacks it fo powerfully, as to produce actual ignition; and even when diluted it not only deftroys the blue colour immediately, but diffipates the greateft part of its fubftance, in the form of vapour, by a flower combuftion, leaving behind a rufty iron-coloured gummo-refinous mafs, foluble in alkohol, and partly fo in water, but of no ufe.

Indigo reduced to powder, and mixed with five or fix times its weight of ftrong fulphuric acid (oil of vitriol), will be attacked with confiderable activity and heat; and in about twenty-four hours it will be diffolved. When acted upon by this acid, the colour of the indigo is rendered more lively and beautiful by the addition of a farther portion of oxygene, though it becomes lefs durable, becaufe the bafis is made weaker by the action and further addition of oxygene; but more of this when treating of the Saxon blue.

The muriatic acid, in its moft concentrated ftate, has no fenfible action upon the pure colouring matter of indigo, though it diffolves fome other parts of it. By an equal mixture of nitric and muriatic acids, indigo was rapidly diffolved, and its colour deftroyed, nearly in the fame way as by the nitric acid only.

Having produced a mixture of vitriolic and muriatic acids, by pouring a fufficient quantity of oil of vitriol upon fea falt, I found it diffolve the indigo more flowly indeed than the fulphuric acid alone; but the folution feemed to anfwer equally well for the purpofes of dying. It muft be obferved, however, that neither the fulphuric, nor even the nitrous acid, when greatly diluted, are capable of diffolving the colouring matter of indigo.

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The oxygenated muriatic acid acts but very feebly upon indigo, whilst in substance; but when dissolved it destroys the colour. Mr. Berthollet availed himself of this circumstance, to obtain a measure for ascertaining the proportionate quantity of colouring matter in different kinds of indigo, by finding how much of the muriatic acid was necessary to destroy the colour of a given quantity of indigo, previously dissolved by sulphuric acid. I think, however, this might be done with certainty, by seeing how much wool a given quantity, so dissolved, would dye of a particular shade. I have found, that, by adding a little manganese to the solution of indigo, by oil of vitriol, the blue colour was destroyed as efficaciously, and in the same way, as by oxygenated muriatic acid.

The tartarous, acetous, phosphoric, fluoric, and other acids, seem to have no action on the colouring matter of indigo.

None of the alkalies, either pot-ash, soda, or ammoniac, whether mild or caustic, have any action upon the colouring matter of indigo, unless when it has been previously dissolved by vitriolic acid, or deprived of a portion of oxygene, as will be hereafter explained; nor has lime water any power of dissolving it.

In the second, and only way of dissolving indigo, without lessening the durability of its colour, there is no one substance, or agent in nature, capable of producing this effect; but it results from the concurrent action of different agents.

Previous

Previous to the uſe of indigo in Europe, the blue dye was obtained ſolely from the iſatis (glaſtum), or woad, of which there are two ſpecies; the iſatis tinctoria (commonly cultivated in this kingdom), and the iſatis luſitannica Linn. of which the laſt is ſomewhat ſmaller than the firſt. This plant being cut down at maturity, waſhed, and then expeditiouſly dryed in the ſun, is afterwards ground in a mill, then placed in heaps, ſecured (by being covered) from the rain, and left to ferment during fourteen or fifteen days; the external and internal parts are then well mixed together by ſtirring, and the whole is formed into balls, piled upon each other, and expoſed to wind and ſun, in order that the remaining humidity may evaporate: but while this is doing, the balls begin again gradually to ferment, become hot, and exhale a portion of ammoniac, or volatile alkali; and if neceſſary, the heat and fermentation are promoted, by occaſionally wetting the maſs until it aſſumes the form in which it is commonly offered for ſale. The proper modes of conducting the fermentation, and the exact times at which it ought to be ſtopped, ſtill remain ſo uncertain, that thoſe who make it their buſineſs to prepare woad, have no certain facts or indications to govern their management in theſe reſpects; and the goodneſs of any particular quantity, or maſs, can never be aſcertained otherwiſe than by the actual uſe which the dyer makes of it. The article is therefore bought and ſold under the greateſt uncertainties reſpecting its true value and fitneſs to anſwer the purpoſes for which it is intended.

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The iſatis contains the baſis of a blue colour, very ſimilar to that of indigo; but, by the proceſs juſt deſcribed, this baſis receives the changes which ariſe from fermentation, without being extracted from the plant, and collected, like indigo, into diſtinct maſſes. Aſtruc, however, ſome years ago, maintained the practicability of obtaining indigo from the iſatis; and this has been lately done in Germany, by a proceſs ſo nearly reſembling that employed for producing indigo, as not to merit a particular deſcription. Mr. d'Ambourney has alſo done the ſame thing lately at Rouen, in ſmall quantities. But it ſeems probable, that, except for aſcertaining the practicability of doing this, no benefit will ever reſult from it, ſince the indigo may doubtleſs be produced in, and imported from, other countries, with much leſs expence than it will coſt when obtained in Europe from woad. Mr. d'Ambourney mentions the "*lymbe* violet," or violet border, as a ſign of the maturity of the paſtel or woad; that in fermenting it with water to make indigo, the liquor on the third day appeared *green*, but the ſurface was covered with a kind of *blue* powder: that on the fourth day the leaves of woad ſeeming ſufficiently macerated, and exhaling an acidofœtid odour, were taken out, and the remaining liquor appeared of an olive colour: that on the fifth day, finding in it no diſpoſition to a ſeparation, and ſubſidence of colouring matter, he put into it a portion of cauſtic ſoap lees, and beat it with rods to promote this precipitation; after which the olive colour became of a duck green, then of a ſlate-coloured blue, with a bluiſh froth. Mr. d'Ambourney found, in fermenting the leaves of

paſtel,

paſtel, that the addition of an alkali, before the green colour was formed, wholly prevented it, and that a putrid fermentation took place in its ſtead. He concludes, that one hundred pounds of the leaves may yield about one pound and a half of indigo.

Woad alone dyes a blue colour very durable, but leſs vivid and beautiful than that of indigo; it is therefore, at preſent, never uſed except with indigo, in what is called the woad-vat, in which it is made to ferment with water, by a ſuitable degree of warmth, and the addition of bran, with other vegetable matters: to theſe, indigo and lime are afterwards joined; and the indigo being deprived of a portion of its oxygene by the fermenting vegetable ſubſtances, is thereby rendered ſoluble by the lime; and being in this way ſoon combined with the colouring matter of the woad, both form a dying liquor, blue or copper-coloured on the ſurface, where it can re-abſorb the oxygenous gas, but green immediately beneath the ſurface, and throughout the whole maſs. When the liquor becomes, and while it continues, green, it is fit for dying; and cloth or wool dyed with it, though they appear green when taken out, become blue immediately, by attracting and combining with the oxygene; the loſs of which had previouſly rendered the liquor of the woad-vat green. The uſe of indigo had ſcarcely been introduced into Europe, before it was prohibited in ſome countries, from a perſuaſion that its colour was fugitive; and in France, under the enlightened adminiſtration of Colbert, the uſe of it was only permitted in a certain ſmall proportion, along with

woad,

woad, in forming the vat juſt mentioned; ſo very liable are mankind to entertain falſe opinions reſpecting the value and properties of dying drugs.

There are various other blue vats in which indigo is diſſolved, and made fit for dying, without being united to woad. Theſe, however, are generally known, and have, moreover, been ſufficiently deſcribed by Hellot, Quatremere, Le Pileur d'Apligny, Berthollet, and others. They differ conſiderably from each other; but in all of them the indigo is firſt deprived of a portion of its oxygene, by the attraction of vegetable or animal ferments, or of the oxyd of iron (ſeparated from copperas); and then it is diſſolved either by lime, or by ſome alkali, either vegetable, mineral, or volatile. The woad-vat firſt mentioned is almoſt the only one uſed for dying wool, and woollen cloths or ſtuffs. Silk is commonly dyed from a different vat, in which indigo (without any woad) by the aid of a ſufficient degree of warmth and of vegetable alkali, with vegetable ferments, bran and madder, is diſſolved, and made to produce a fine green liquor, with a bluiſh copper-coloured ſcum on the ſurface, &c. Indigo, however, is incapable of dying ſilk of a *deep* blue colour, without the help of archil, or ſome other colouring matter.

Cotton is dyed in a blue vat, into which indigo, ground either in water, or in a cauſtic alkaline ley, is put, with two or three times its weight of lime, previouſly ſlacked in a ſufficient quantity of water, and about one-fourth leſs of copperas

copperas (sulphat of iron) than of lime. When this mixture is made, a part of the lime unites with the acid of the copperas, forming calcareous sulphat or selenite, and at the same time precipitates the oxyd of iron, which, not being saturated with oxygene, attracts so much of that which was combined with the indigo, as to render this last substance soluble, by the lime remaining over and above what was employed to saturate the sulphuric acid. The beginning dissolution of the indigo may be perceived by a shining copper-coloured pellicle, which forms itself on the surface of the mixture, while the liquor itself becomes green, and afterwards gradually inclines more and more to the yellow, as the solution advances. When it is completed, and the liquor settled, the cotton, yarn, or stuffs are to be dyed in it: at first they will appear yellow when taken out, but by absorbing the oxygene, they rapidly assume and pass through the different shades of green, and in a few minutes become blue, the oxygene regenerating the indigo in the pores of the cotton. Mr. Haussman, of Colmar in Alsace, who, with a good stock of chymical knowledge, daily practises the arts of dying and callico printing, lately published an excellent " Memoire sur l'Indigo & ses dissolvans," in the Journal de Physique, &c. for March 1788, in which he mentions, that the change of colour from yellow to blue, in cottons dyed as before mentioned, may be greatly accelerated, and their colours made deeper than they would otherwise become by plunging the dyed cottons, when first taken out of the vat, into water soured by vitriolic acid, which hastens the regeneration of the indigo, and moreover diſſolves and carries off a portion of white calcareous ſulphat or ſelenite, which would weaken the ſtrength or intenſity of the blue colour.

If the colour of the vat be not all uſed ſoon after it has been prepared, it will require occaſional ſtirring; ſince the diſſolved indigo, by continually abſorbing oxygenous gas from the atmoſphere, will be conſtantly reviving, in conſiderable quantities, upon the ſurface of the liquor; and the indigo ſo revived can only be rediſſolved by being again ſubjected to the combined action of lime, and oxyd of iron: if by length of time theſe ſhould become perfectly ſaturated with oxygene and carbonic acid, before the blue colour is all uſed, a farther portion of each muſt be added, and ſomewhat more of lime than of copperas.

Mr. Hauſſman obſerves, that all the precipitates of iron, whether obtained from ſolutions of that metal by the mineral, vegetable, or animal acids, will ſerve, with quick lime, to diſſolve indigo, as well as that of green vitriol, provided, or ſo long as they retain the property of abſorbing vital air; but that a nitric ſolution of iron, or the ruſt of it, or any other preparation where it exiſts in an ochrous form, not attracted by the magnet, nor capable of attracting pure air, will be wholly uſeleſs towards producing a diſſolution of indigo, though employed with an exceſs of quick lime, or of cauſtic alkali. He conceives, that the precipitate of iron, obtained from copperas, promotes the diſſolution of indigo by its phlogiſton; and that he cannot ſatisfactorily explain

plain this effect upon the new syſtem, unleſs by ſuppoſing, that the oxygene only adheres to the integrant molecules of the indigo, without an actual combination (which he thinks improbable); and that the oxygene having ſtronger affinity to the precipitate of iron than to the indigo, quits the latter to unite with the former; while the indigo, in giving up the oxygene, unites with the lime, or cauſtic alkali, and is diſſolved by them; which indeed ſeems to be the true explanation.

Mr. Hauſſman further obſerves, that cauſtic alkali, with fine iron filings, inſtead of the precipitate from copperas, would not diſſolve indigo; but that (regulus of) antimony, brought into the form of a powder, diſſolved it perfectly with the cauſtic alkali, or quick lime ſlacked by water; though the calces, or oxyds of antimony, in this way, produced no ſuch effect: nor did any precipitates of copper: on the contrary, they all ſeemed rather to haſten the regeneration of indigo, after it had been diſſolved by ſome other means: and he adds, that ſome dyers avail themſelves of this effect, to obtain, at once, all the colour remaining in a blue vat (after it has been too weak to dye properly), by paſſing cottons through water in which a little ſulphat of copper (blue vitriol) has been diſſolved, and then dying them in the vat intended to be exhauſted, where the ſolution of copper ſpeedily precipitates, and revives the remaining indigo in the pores of the cotton.

I have repeated moſt of Mr. Hauſſman's experiments, with different precipitates, or oxyds of iron, and with effects nearly ſimilar to thoſe he deſcribes. I found that neither the ruſt of iron, nor the nitric oxyd of it, would aſſiſt in the diſſolution of indigo; obviouſly becauſe they were both already ſaturated with oxygene: I alſo found, that even a precipitate of copperas failed for the ſame reaſon, when, inſtead of ſeparating it by lime, it was made by diſſolving copperas in water, and leaving it for ſome weeks expoſed to the air in warm weather, where the iron was farther acted upon, and ſaturated, as well as precipitated, by the oxygene which it gained from the atmoſphere.

It is nearly in the ſame way, and upon the ſame principle, that the topical indigo blue, employed by calico printers for penciling, is made: the ingredients of this compoſition are employed in different proportions in different places; and will ſucceed with very conſiderable latitude in this reſpect: indeed, the different qualities of indigo neceſſarily render it impoſſible to preſcribe any exact proportions, which ſhall be always equally efficacious and ſuitable.

Mr. Hauſſman mixes twenty-five gallons of water with ſixteen pounds of indigo, well ground (or a greater or ſmaller quantity, according to the quality of the indigo, and the depth of colour wanted), to which he adds thirty pounds of good carbonate of pot-aſh, placing the whole over a fire; and as ſoon as the mixture begins to boil, he adds, by a little at a time, twelve pounds of quick lime, to render the alkali cauſtic, by abſorbing its carbonic acid, or fixed air. This being done, twelve pounds of red orpiment are alſo added to the mixture, which is then ſtirred, and left to boil for ſome little time, that the indigo may be perfectly diſſolved; which may be known by its giving a yellow colour, immediately upon being applied to a piece of white tranſparent glaſs. M. Oberkampf, proprietor of the celebrated manufactory at Jouy near Verſailles, uſes a third more of indigo; and others uſe different proportions, not only of indigo, but of lime, pot-aſh, and orpiment; which all ſeem to anſwer with nearly equal ſucceſs: but with the beſt copper-coloured Guatamala indigo, it is certain that a good blue may be obtained from only half the quantity preſcribed by Mr. Hauſſman, by uſing as much ſtone, or oyſter ſhell lime, as of indigo, nearly twice as much pot-aſh, and a fourth part leſs of orpiment than of indigo. This compoſition is greatly defended from air by gum, which ſhould be diſſolved in it whilſt hot; and it ſhould afterwards be kept ſecluded as much as poſſible from the contact both of vital air, and carbonic acid gas or fixed air.

Indigo diſſolved in this way, for penciling or printing, I ſhall hereafter call *topical blue*—its ſtrong tendency to attract oxygene from the atmoſphere, and to be thereby regenerated, renders its uſe ſubject to many difficulties; it being almoſt impoſſible to pencil, and more ſo to print, a piece of cotton throughout of the ſame ſhade, with the beſt endeavours, to apply it equally, and quickly, by the moſt expert and careful hands. It will give a faſt colour only ſo long as it continues yellow, or, at moſt, of a yellowiſh green; as ſoon as it appears blue, the indigo may

may be conſidered as revived, and incapable of fixing on the cotton: in this caſe, however, it may be re-diſſolved, by adding more cauſtic alkali and orpiment. The clear liquor only, when gummed, is to be uſed; but it is not to be ſeparated from the ſediment, which helps to preſerve it in a ſtate of diſſolution.

In making the before-mentioned compoſition, a copper-coloured pellicle appears on the ſurface of the liquor as ſoon as the indigo begins to diſſolve; and this pellicle becomes violet, and at laſt blue, by longer expoſure to the atmoſphere. Mr. Hauſſman obſerves, that the ſame pellicle ariſes, with the ſame appearances, if the ſolution of indigo be put into contact with either the dephlogiſticated or the vital airs; but that, under the receiver of a pneumatic machine, it diminiſhes in proportion as a vacuum is produced; and that it does not appear at all in the inflammable or the phlogiſticated airs. Mr. Hauſſman farther obſerves, that if, inſtead of orpiment, ſulphur and white arſenic, of which it is formed, be employed, either together or ſeparately, with quick lime and pot-aſh, no ſolution of indigo will take place; and this will alſo be the caſe, even where orpiment is uſed, if quick lime be not employed to render the alkali cauſtic. That having put indigo, diſſolved by orpiment, lime, and pot-aſh, into contact with dephlogiſticated air (oxygenous gas), obtained by diſtillation from nitre, he found in a little time that ſeven-eighths of it were abſorbed by the ſolution of indigo, and the remaining eighth was azote only (phlogiſticated air); and the blue was rendered unfit for uſe, the indigo being re-

 generated,

generated, as he found it, at other times, from the application of fixed air (carbonic acid); but with this difference, that a part of the alkali remained cauſtic, while another part of it combined with the vitriolic (ſulphuric) acid (formed by the union of the ſulphur to a part of the abſorbed oxygene), and thereby produced vitriolated tartar (ſulphat of pot-aſh): another part of the oxygene, ſo abſorbed, had combined with the arſenic, and changed its metallic form to that of an oxyd, in which ſtate it had united to the cauſtic alkali; and the reſt of the abſorbed oxygene had combined with, and regenerated the diſſolved indigo.

Mr. Hauſſman was indeed inclined to explain the ſolution of indigo, according to the phlogiſtic ſyſtem, by conſidering it as reſulting from a greater affinity which phlogiſton was ſuppoſed to have with indigo than with arſenic, and that it was the action of this phlogiſton, joined to that of the cauſtic alkali, which operated the diſſolution in queſtion; but that the phlogiſton, having ſtill a greater affinity with dephlogiſticated air than with indigo, abandoned the latter as ſoon as the former was preſented to it, leaving the indigo in its regenerated form, the alkali alone not being ſufficient to preſerve it in a ſtate of ſolution. But a much happier, and more natural explanation of theſe effects, is afforded by the new doctrine, as already ſtated; and it is ſtrongly ſupported by all that we know of the nature of indigo, and the properties of thoſe agents employed to diſſolve it. Experiments made by Dr. Prieſtley, and others, evidently prove that iron, in the ſtate in which it exiſts in copperas,

copperas, or when recently precipitated from a ſolution of copperas, forcibly attracts, and combines with, vital air brought into contact with it; and it is alſo well known, that the ſulphuret of arſenic (orpiment) does the ſame, when diſſolved by an alkali.

Mr. Hauſſman found, that the ſulphuret of antimony (crude antimony) aſſiſted in diſſolving the indigo, for topical blue, as well as orpiment, but that it was unfit for penciling or printing; becauſe the antimony was precipitated, in the form of a mineral kermes or golden ſulphur, tarniſhing the blue colour, and adhering to the linens or cottons almoſt as ſtrongly as the indigo itſelf. The oxyd of antimony, with ſulphur, did not produce a ſolution of the indigo, when uſed inſtead of the crude antimony; though antimony, in its metallic ſtate (*i. e.* the regulus), reduced to powder, had occaſioned the diſſolution of indigo in the ſame way, and as well as the crude antimony. He found, what is very remarkable, that no ſuch effect was produced by the filings of zinc; though when heated it has great affinity with oxygene. He attempted, in vain, to diſſolve indigo, by a combination of ſulphur with the other metals (beſides antimony and arſenic); and he attributes his want of ſucceſs to the circumſtance of their being diſſolved with difficulty, or perhaps not at all "par la voie humide," in the cauſtic alkalies.

Beſides repeating a great part of theſe experiments, and with ſimilar effects, I have made ſome, which, probably, were not attempted

 before;

before; and ſeveral of them with effects highly deſerving of notice.

I boiled, for two hours, the fineſt blue Guatamala indigo in water, with about four times its weight of highly-burnt oyſter-ſhell lime, which I took hot from the fire, and put into the water, to ſee whether lime had, in this way, any action upon indigo: the better to aſcertain this, I put into the boiling liquor a ſmall piece of white broad cloth, and another of white calico: in about an hour both were taken out, and the broad cloth was ſo far diſſolved by the lime, that it crumbled on being preſſed between my fingers; but the calico did not ſeem hurt; though neither were in any degree coloured by the indigo. I afterwards added a quantity of pure carbonated pot-aſh, equal to that of the lime which had been uſed; and I continued the boiling for two hours more, and then leaving the liquor quiet, I ſoon found the indigo and lime had ſettled to the bottom, and left the water perfectly colourleſs. The next day the mixture was well ſtirred, and boiled again for two hours; and being left to ſettle, it again gave the ſame proof of there having been no diſſolution of the indigo. I had at hand about a pound of an oxyd of tin, prepared ſome time before (for a different purpoſe), by putting two pounds of common ſingle aqua fortis, diluted with as much water, upon a quantity of tin, not in very ſmall pieces, and leaving the former to act ſlowly upon the latter during ſeveral months, until all its oxygene was exhauſted; after which I found the oxyd, or calx, formed into lumps as large as a walnut,

and

and ſettled at the bottom. The clear liquor being decanted from the oxyd of tin, the latter was ſlightly rinced with water, and being dried, remained in ſolid lumps. Some of theſe, weighing about twice as much as the indigo which I had employed, were then put into the cauſtic alkaline liquor, in which I had ineffectually endeavoured to diſſolve the indigo; and in leſs than five minutes I perceived ſigns of a beginning diſſolution, which increaſed rapidly; and in half an hour the liquor had paſſed through all the ſhades of green, and become yellow, except at its ſurface, which was covered by a fine copper-coloured pellicle, of a ſhining metallic appearance. Silk and cotton dipped into the liquor, were taken out yellow, and became green, then aſſumed a ſhining copper-colour, and afterwards changed to violet, and then became blue; and were found, by waſhing, to be permanently dyed. Part of the ſame liquor, gummed, and applied topically, anſwered as well for penciling as any topical blue I ever ſaw. Another part of it, being poured into a white glaſs phial, ſo as to fill it to the top, with a portion of the lime and oxyd of tin, ſhaken all together, but without gum, and being well ſtopped and left at reſt, in a few days became as pellucid and colourleſs as clean water, excepting only the ſediment at bottom. Upon unſtopping the phial, the ſurface of the liquor, coming into contact with the atmoſphere, and abſorbing oxygene, inſtantly became green and blue; and upon re-ſtopping the phial, and ſhaking it, the indigo forming this blue ſurface was diſperſed through the maſs of liquor, and tinged it of a beautiful greeniſh yellow; but there being a ſufficient quantity of oxyd of tin unſaturated, the oxygene was ſoon abſorbed, and the liquor again rendered colourleſs: when, inſtead of the oxyd of tin, I employed the metal finely granulated, it produced no effect towards diſſolving indigo; and on trying tin, which had been calcined with ſaltpetre in a crucible, I found that it not only did not diſſolve the indigo itſelf, but prevented it from being diſſolved by the oxyd of tin (produced by the aqua fortis, as juſt mentioned), or by crude antimony, or copperas either ſingly or combined; indeed it was with difficulty diſſolved, when orpiment, in a large proportion, was added to all the above; this I alſo found to be the caſe of tin, calcined alone in a crucible by ſtrong heat: biſmuth calcined in like manner, equally obſtructed the ſolution of indigo. Probably in theſe caſes the metals ſo calcined not only do not attract the oxygene of indigo, but let go that which they had imbibed during calcination.

In the courſe of my experiments upon indigo, I was induced to make trial of refined ſugar, inſtead of orpiment; and I found that the ſugar acted very efficaciouſly in diſſolving indigo, with the uſual appearances, and producing a topical ſubſtantive blue, as permanent, and every way as good as any in uſe. I afterwards tried coarſe brown ſugar, and I found it at leaſt as effectual as the refined, for this purpoſe; it then occurred to me, that this might be a valuable ſubſtitute for orpiment, the uſe of which, as a conſtituent part of the topical blue, may, from its poiſonous quality, ſometimes produce miſchief, and always gives the compoſition an unpleaſant

unpleaſant ſmell. I moreover conceived, that, by employing a large proportion of brown ſugar, it might be practicable to thicken the mixture ſufficiently for penciling or printing, and thereby avoid the greater expence of gum for that purpoſe; and upon trial, this alſo proved to be the caſe, the ſugar thickening the ſolution ſufficiently, and afterwards drying as expeditiouſly as when thickened by gum, contrary to what I had apprehended as probable, from recollecting that ink, when thickened by ſugar, was diſpoſed to retain moiſture, and dry very ſlowly. I think, moreover, that when the ſolution of indigo is both made and thickened by ſugar, in this large proportion, the latter, by being able to abſorb a larger quantity of oxygene from time to time, enables the topical blue to bear expoſure to the atmoſphere ſomewhat longer, without a regeneration of the indigo, than when it is diſſolved by only the uſual proportion of orpiment. I think, therefore, that this way of compoſing a ſubſtantive topical blue, by employing coarſe brown ſugar, inſtead of both orpiment and gum, is deſerving of particular attention, as forming a compoſition free from all poiſonous qualities, and at the ſame time cheaper and better than that generally uſed. Melaſſes will ſerve as well as brown ſugar to promote the diſſolution of indigo; but I think not ſo well to ſupply the place of gum in thickening the compoſition.

Sugar uſed in this way, ſeems to act like orpiment in combining with oxygene; which it is ſtrongly diſpoſed to do in other circumſtances. M. Berthollet, in the ſecond volume of the Annales

nales de Chymie, mentions, that, in diſtilling the ſulphuric acid upon different animal and vegetable ſubſtances, he found none of them ſo proper to form a large quantity of ſulphureous acid; which it could only produce by its great affinity with oxygene.

I found, upon different trials, that, with the help of pot-aſh and lime, I could not diſſolve indigo, either by ſulphur, or white arſenic, or charcoal, or oxyd of biſmuth, or of lead (minium), or of zinc (lapis calaminaris), or of manganeſe, or the alkaline ſolution of flints, or of the earth of alum, or by magneſia. I was equally unſucceſsful with copper, as well in its metallic form, as in all the uſual preparations of it: and indeed when indigo was mixed with verdigriſe, lime, and pot-aſh, as uſual, it not only did not diſſolve it, but the verdigriſe prevented the action of all other agents upon it, inſomuch that the indigo remained undiſſolved, notwithſtanding the combined action of crude antimony, orpiment, oxyd of tin, copperas, and ſugar in large doſes, any one of which, with the quick lime and pot-aſh, would have effectually diſſolved the indigo, had there been no verdigriſe or copper in contact with it. The ſulphat of zinc (white vitriol) was almoſt as adverſe to the diſſolution of indigo; for it not only did not contribute thereto, with pot-aſh and lime, but it prevented any ſolution from taking place by the oxyd of tin, crude antimony, ſugar, and copperas, applied one after the other: though when to all theſe a large portion of orpiment was added, and the mixture kept ſome time in a boiling heat, the indigo did at length diſſolve, but

but with great difficulty and tardinefs. Vermilion I found, on repeated trials, incapable of contributing, in any degree, to diffolve indigo with lime and pot-afh; though it did not obftruct the diffolution thereof, when orpiment was added. Camphor appeared to have no effect.

The topical blue, when made, is often applied by the pencil upon fpots or figures previoufly dyed yellow, in order to produce a permanent green; but the cauftic alkali contained in it, efpecially when employed too freely, feems to weaken the yellow on which it is laid. Wifhing to remove this difficulty, I thought of neutralizing the alkali, at leaft in fome degree, fo as to make it harmlefs in this refpect, without, at the fame time, rendering the blue lefs efficacious. I could not, however, expect to do this, with either the nitric, fulphuric, or acetous acids; becaufe they are now univerfally allowed to derive their acidity from oxygene; which, if applied to indigo, neceffarily would produce the regeneration of it, and make it unfit for penciling or printing. I knew, however, that though Mr. Lavoifier had, from analogy, been induced to conclude that the muriatic acid derived its acidity, like moft others, from oxygene, yet there was good reafon to doubt its exiftence in muriatic acid; that this acid, inftead of being fixed, was rendered more volatile by oxygene, and that, inftead of becoming more, it was made lefs acid by every addition of oxygene; circumftances which do not feem to indicate that this is the acidifying principle of muriatic acid. I knew alfo, that Mr. Berthollet

was,

was, at length, nearly convinced that the muriatic ought to be deemed a radical acid, which, by the means of a certain portion of oxygene, gained properties ſimilar to thoſe of the nitrous and ſulphureous acids, and, being ſuper oxygenated, acquired relative properties, ſimilar to thoſe of the nitric and ſulphuric acids: I reſolved, therefore, to try their different effects upon the topical blue, and for this purpoſe I mixed the acetous, ſulphuric, and nitric acids, each ſeparately, with a portion of it; and I found that, even in ſmall quantities, they inſtantly deſtroyed the green and yellow colours of the diſſolved indigo, and, by reviving it, rendered the mixture uniformly blue; producing, at the ſame time, a conſiderable efferveſcence. Muriatic acid, however, acted differently; for, though it produced ſome efferveſcence, it neither rendered the mixture, nor even its efferveſcing ſurface, which was covered with froth, blue, but both remained green, while ſecluded from the contact of atmoſpheric air, by being incloſed in a veſſel well ſtopped; and I found it practicable to neutralize the alkali completely, without rendering the indigo unfit to produce a faſt blue colour, or a green, upon yellows, if applied quickly; but when the topical blue, thus neutralized, was kept ſome time, the indigo, being deprived of the alkali which had held it in ſolution, gradually ſubſided in a great degree, and became unfit to be applied in this way. There is, however, I think, an intermediate degree to which the alkali may be neutralized, without precipitating the indigo, in any conſiderable quantity, for ſeveral weeks at leaſt, and which will be ſufficient to prevent the alkali from ex-

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ercifing any action injurious to the yellow colours upon which the blue may be laid. The topical blue made with fugar effervefced but very flightly when mixed with muriatic acid, and therefore it has, in this refpect, an advantage over the blue made with orpiment. The fluoric is another acid, in which the exiftence of oxygene has never been proved, or made probable, otherwife than by analogy. This circumftance led me to try it alfo with the topical blue; when I found its effects very fimilar to thofe of the muriatic acid. The eighth part of a phial being filled with the fluoric acid, and fome of the blue prepared with fugar, as before defcribed, being poured upon it, no effervefcence appeared, and the mixture remained of a yellowifh green colour; cotton plunged in it imbibed, and continued of the fame colour, until it was taken out and expofed to the air, when it gradually affumed a very deep, ftrong, blue colour, which, upon being wafhed in warm foap fuds, was found perfectly fixed. The fame experiment, with fome variation of circumftances, was feveral times repeated, and always with fimilar effects; and upon the whole, the fluoric acid feems even better fuited than the muriatic to neutralize the alkaline part of the topical blue, where it may be thought expedient to have it in a neutral ftate; though, I think, fomething fhort of this is all that can be wanted, or fhould be attempted, in the bufinefs of calico printing. I am fenfible, that, though thefe facts afford new reafon for not believing that oxygene is the acidifying principle of the muriatic and fluoric acids, they do not abfolutely prove the contrary; becaufe they may contain oxygene, fo intimately united to their refpective bafes,

bafes, as that it can neither be feparated, nor left at liberty to manifeft any of its ufual properties; but, allowing this to be poffible, we muft not, I think, fuppofe it to be really the cafe, without more probability thereof than yet appears. This indeed was partly the cafe with vitriolic ether, which, being added to topical blue prepared with fugar, did not much change its colour, nor prevent it from being fixed in fome degree on cotton.

Wifhing to know what effects would refult from a ftronger action of pot-afh, lime, and orpiment upon indigo, I diffolved it with three times the ufual portion of thefe agents, and having afterwards fhaken the whole mixture well together, I filled a large tranfparent glafs phial therewith (but without any gum), and having fecured it from all contact with external air, by a glafs ftopper covered with wax, I left it in that ftate for three months, fhaking the phial occafionally, that the more fluid part of the mixture (which foon became nearly colourlefs) might be acted upon more equally, by the lime, &c. at bottom; after which, the phial being opened, I found that the mixture (which gave a deep permanent blue to cotton, when firft made) had become incapable of manifefting any colour by the contact of atmofpheric air, or by the addition of fulphuric, fluoric, and other acids; the indigo having been not only deprived of the oxygene neceffary to its colour, but probably rendered incapable of re-uniting with it as formerly, in confequence of a decompofition of its vegetable bafis, or a new combination thereof with one or more of the agents in queftion, too

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intimate to be overcome by any of the usual means of regenerating indigo. Here we have an instance of one of the most permanent of colouring matters losing its colour; not by any thing like *combustion*, which necessarily requires the presence and combination of vital air, but by means which seclude it from, and deprive it of, all such air.

In forming some of the indigo vats, it has been usual to employ a considerable quantity of madder and weld, though neither of them, in this way, can possibly do any good as colouring substances, their colours having no permanency without an aluminous, or other basis, as will be hereafter explained; they can therefore produce no benefit in any other way than as promoting fermentation; for which purpose many cheaper matters would prove infinitely more efficacious, particularly melasses, carrots, parsnips, shells of green peas, &c. &c.

It is to be observed, that all the preceding means of rendering indigo soluble, by abstracting a part of its oxygene, serve only to bring it back to the state in which it existed while retaining its green colour in the process of fermentation, before its minutest particles had been collected together, in a concrete blue form, by agitation, and the farther application of oxygene. I have already intimated a persuasion, that the colouring matter of the indigo plant, in this fluid state, is not only fit for dying, but that the blue colour dyed with it, would, like that of the isatis, or woad, be yet more permanent than that given by the indigo,

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after it has been made to aſſume a concrete form; becauſe its baſis, even by the leaſt deſtructive ways of diſſolving it, will, I think, neceſſarily be in ſome degree weakened, as all other vegetable colours are found to be, by the action of ſuch powerful agents as are requiſite for that purpoſe; and I conceive that the very durable blues which are known to be given by particular people in ſome parts of Aſia and Africa, muſt be derived from the colouring matter of the indigo plant, employed when firſt extracted by ſteeping and fermentation. The Chineſe are ſaid to employ the indigo plant for dying in this way; and it appears that the Africans employ it in a way nearly ſimilar, at leaſt with reſpect to the ſtate of its colouring matter, applied as a dye.

According to Mr. Clarkſon, "it is well known, at leaſt in the manufacturing towns, that the African dyes are ſuperior to thoſe of any other part of the globe." "The blue (continues he) is ſo much more beautiful and permanent than that which is extracted from the ſame plant in other parts, that many have been led to doubt whether the African cloths brought into this country were dyed with indigo or not. They apprehended that the colours in theſe, which became more beautiful upon waſhing, muſt have proceeded from another weed, or have been an extraction from ſome of the woods which are celebrated for dying there. The matter, however, has been clearly aſcertained: a gentleman procured two or three of the balls, which had been juſt prepared by the Africans for uſe: he brought them home, and upon examination found

found them to be the leaves of indigo rolled up, and in a very ſimple ſtate.

M. Adanſon, mentioning the indigo plant cultivated by the negroes of Senegal, ſays, theſe people do not take much pains to draw the dye out of this plant; they are ſatisfied with gathering the leaves at any time of the year, with pounding them in a mortar to reduce them to a paſte, and with making them up into loaves, in order to preſerve them dry. When they want to make uſe of them, they diſſolve them in a kind of lye, made of the aſhes of an unctuous plant which grows in their fields, and is by them called *rhemi* (Portulacca Marina, &c. Plum. Cat. p. 6.). This diſſolution, adds he, imbibes a tincture of the indigo, into which they dip their linen cold, as often as they think neceſſary, according to the deepneſs of the colour. See his Voyage to Senegal, the Iſle of Goree, and the River Gambia. 8vo.

The indigo plant, when uſed in the way which M. Adanſon deſcribes (with too much brevity indeed), ſeems to be in a ſtate reſembling that in which the iſatis or woad is commonly employed, as before mentioned; and unleſs the freight would prove too expenſive, I ſhould think it might be advantageouſly imported in balls, like thoſe mentioned by him, to aſſiſt in forming indigo vats, though it would not anſwer in this ſhape for producing what is called the Saxon blue, by a combination with ſulphuric acid.

### *Of Saxon Blue.*

Indigo diſſolved by the ſulphuric acid, acquires a more lively though a leſs durable colour than it naturally poſſeſſes, or can be made to receive by any other means; probably becauſe it thereby acquires an additional portion of oxygene. The application of this blue as a dye was firſt made by Counſellor Barth at Groſſenhayn in Saxony, about the year 1740. He employed, beſides indigo and ſulphuric acid, lapis caliminaris and antimony, mixing them with the oil of vitriol firſt, and adding the indigo afterwards. According to ſome, he alſo employed allum; but all theſe additions being found uſeleſs, were afterwards laid aſide.

M. Hauſſman obſerves, that a ſmall piece of indigo put into a little ſulphuric acid of proper ſtrength, becomes very ſoon coloured upon its external ſurface, firſt of a greeniſh yellow, and afterwards of a deep green, and finally of a blue; that in evaporating indigo, which had been diſſolved by this acid in a glaſs veſſel placed on a ſand heat, there eſcaped a portion of ſulphureous or volatile vitriolic acid, and of hydrogene (inflammable gas), which upon applying to them the flame of a candle, gave ſlight marks of inflammation; that the expanſion of the indigo, and ſeparation of ſulphureous inflammable vapours, during its ſolution by oil of vitriol, leave no room to doubt of the ſtrong action of the latter upon the conſtituent parts of indigo; and he therefore concludes, that we ſhould err in conſidering the indigo as having ſuffered no alteration by the ſulphuric acid, and in comparing a ſolution of it in this way to thoſe other ſolutions already deſcribed, in which the baſis of indigo ſuffers little or no injury; that the blue dyed by theſe ſulphuric ſolutions of indigo, can hardly be deemed a faſt colour, ſince it is eaſily extracted by ſoap in boiling water, and changed by alkali to an olive colour, more or leſs yellow, according as the alkali is more or leſs cauſtic; and ſince the adheſion of this blue to linen and cotton is ſo feeble, that even cold running water will carry it off.

Bergman aſcribes the want of greater permanency in the Saxon blue to the uſe of ſulphuric acid not ſufficiently concentrated. He uſed an acid whoſe ſpecific gravity, compared to that of water, was as 1900 to 1000, and employed eight pounds of this acid to diſſolve one pound of indigo. I believe, however, that he has been miſled on this ſubject, and that Pœrner is much nearer the truth, when he ſays, that the beſt proportion for diſſolving indigo is only four times its weight of good pure oil of vitriol; and that where more is uſed, the blue is leſs permanent. I am even inclined to think that the blue will prove more durable, if this laſt quantity of acid be diluted with an equal portion of water as ſoon as the indigo is put to it, and the mixture left in a warm ſituation 48 inſtead of 24 hours for the indigo to diſſolve; becauſe, by a ſlower and more moderate action, I think the baſis of the indigo will be leſs weakened; at leaſt I have frequently diſſolved indigo in this way, and the colour has appeared to be more durable than when it was diſſolved by an undiluted acid. Perhaps even a farther dilution might ſtill leave the acid of ſufficient force for diſſolving the indigo perfectly. But this I ſhall endeavour to aſcertain hereafter by more accurate experiments than I have yet made. The indigo being diſſolved, Mr. Pœrner adds as many ounces of dried pot-aſh as there were of indigo in the ſolution, which produces an effervefcence; and after twenty-four hours, he adds eight pounds and an half of water for each pound of oil of vitriol employed, and puts the whole into a glaſs veſſel for uſe. Inſtead of pot-aſh, I have uſed clean chalk, and this even in ſuch quantities, as to ſaturate the vitriolic acid. The indigo was then precipitated with the chalk, and being collected in a ſolid maſs, it was ſtill capable of dying a blue on wood, though it took much more ſlowly than in the ordinary way of dying Saxon blue, in which the colour applies itſelf ſo rapidly to wool or woollen cloth, as to render it difficult, with the utmoſt care, to prevent its taking unequally; a defect which might probably be obviated by a ſmall portion of chalk. It is to prevent this, that M. d'Ambourney adviſes, where deep Saxon blues are wanted, to paſs the cloth at different times through veſſels containing only what might ſuffice for weak colours, in order that the blue may, by theſe partial applications, be made to take with more evenneſs. Silk, dyed along with wool, takes a much weaker colour, (I mean with the addition of chalk,) becauſe it has leſs affinity with the indigo than wool has. This preparation of indigo, however, would not give a deep blue, becauſe being united with ſo large a portion of white calcareous earth or lime, the blue colouring particles could not be ſufficiently condenſed for that purpoſe. Pœrner conceives the Saxon blue to be rendered more durable by previouſly preparing the cloth with allum. The ſolution of indigo by ſulphuric acid, is uſually called by dyers chymical blue. It ought, however, according to the new nomenclature, to be termed

termed ſulphate of indigo; a name by which I ſhall hereafter diſtinguiſh it. When applied to wool, the blue colour is much more permanent than while in a fluid ſtate; for though a little manganeſe, added to the ſulphate of indigo, inſtantly changed its blue to a brown colour, wool, which had been previouſly dyed blue with ſome of the ſame preparation, was not diſcoloured by the action of manganeſe diſſolved in ſulphuric acid. I do not know that a black was ever produced by the ſulphate of indigo, or by any other preparation of that drug alone. Mr. John Wilſon, who has greatly contributed to improve the art of dying at Mancheſter, maintains, that though a redundance of colouring matter will increaſe the force and body of a colour, yet that no repeated dyings of blue will become black. I have, however, now before me two pieces of cloth, one of which is the deepeſt and pureſt black perhaps ever ſeen, and was dyed by me, very lately, from ſulphate of indigo, employed alone, though in an unuſual quantity; the other is of a fine Saxon blue, and was cut off from the firſt, before it had taken up ſo much of the blue colour as to become black. I lately found alſo, in making the topical blue, that a ſmall piece of cotton, which I had thrown into the mixture, and which, being forgotten, had remained there forty-eight hours, was, when taken out, of a *full black*, ſo permanently fixed, that neither lemon juice nor alkalies ſeemed capable of impairing it. I could not in one or two trials afterwards ſucceed in producing a ſimilar black on linen or cotton; and it muſt be remarked, that when I produced that which is the laſt mentioned, it was in a mixture where I had

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at firſt put ſome mangane$\text{ſe}$, to ſee whether it would promote the diſſolution of indigo; and finding it did not, I had afterwards added more than the uſual proportion of orpiment, one or both of which additions may have contributed to the black in queſtion.

The ſulphuric acid, or oil of vitriol, as commonly prepared, contains a ſmall portion of the nitric, which, however ſmall, neceſſarily does ſome harm in forming the ſulphate of indigo. Mr. Chaptal obſerves, that he has ſeen the colour fail, and the ſtuffs intended to have been dyed ſpoiled by this fault in the ſulphuric acid employed for that purpoſe, which ought therefore to be guarded againſt as much as poſſible.

The indigo of all others moſt preferred for Saxon blues, is the blue or Flora of Guatamala, which indeed is ſcarce ever employed for any other ſpecies of blue, at leaſt in this country. The other kinds, and eſpecially the copper, when mixed with oil of vitriol, efferveſce ſometimes very ſtrongly, in conſequence of the extrication of fixed air, the preſence of which may eaſily be accounted for, by recollecting that lime is frequently employed to accelerate the ſeparation and precipitation of the minute particles of indigo, while in the veſſels called beaters: and here it will be proper that I ſhould offer ſome conjectures on the cauſe of the different colours of indigo; and as a foundation for theſe, I muſt remark, that the flora or blue indigo of Guatamala is much lighter than the violet,

violet, and that this laſt is lighter than the copper-coloured. From the lightneſs of this *blue* indigo, and from its not effervescing with acids, when diſſolved by oil of vitriol, there is the ſtrongeſt reaſon to conclude that no lime is employed to accelerate the ſeparation and precipitation of its colouring matter in the beaters; ſince if there had been any, it would have increaſed the ſpecific gravity of the indigo, and by abſorbing carbonic acid, would neceſſarily have cauſed an effervescence in making the ſulphate of indigo: taking it therefore for granted, that no lime is employed to ſeparate and precipitate the colouring matter, it would neceſſarily follow, that, to obtain ſuch ſeparation and precipitation, the agitation muſt have been continued longer than would otherwiſe have been neceſſary, and the unavoidable conſequence would have been the combination of a larger proportion of oxygene with the colouring particles ſo expoſed to it, than what takes place with thoſe ſeparated by lime: it will therefore follow, that indigo, obtained in this way, will contain a greater portion of oxygene than the other; and it ſeems natural to conclude that the blue colour is occaſioned thereby. To aſcertain, however, the juſtice of this concluſion as far as I was able, I took ſome of the lighteſt and blueſt Guatamala indigo, and diſſolved it by lime, pot-aſh, and orpiment, as uſual; one effect of ſuch ſolution we know to be the taking away from the indigo a conſiderable part, at leaſt, of its oxygene; and I accordingly found, as I have done in all caſes where indigo was diſſolved for the topical blue, that the diſſolution was accompanied with a bright ſhining copper-coloured pellicle upon the ſurface of the liquor, which of itſelf was of a greeniſh yellow underneath. The production of this pellicle may be eaſily explained by recollecting that the diſſolved indigo, which has loſt its oxygene, and become thereby of this greeniſh yellow, being at its ſurface in immediate contact with the oxygenous gas of the atmoſphere, regains a part of what it had loſt, and thereby becomes copper-coloured; but ſwimming as it does upon a mixture diſpoſed to attract oxygene, it cannot in this ſtate acquire and keep ſo much thereof as the indigo itſelf formerly had while it was of a blue colour; and therefore, ſo long as the body of the liquor remains yellow or green, the pellicle covering it will be only copper-coloured, though conſiſting of a colouring matter which was formerly blue, and which would have become ſo again, if, being diſſolved, it had been thinly applied to linnen or cotton, and brought ſufficiently into contact with the oxygene of the atmoſphere. As therefore this blue indigo had apparently become copper-coloured, only by having leſs oxygene than before, is there not from this circumſtance an additional reaſon to conclude that the copper-coloured indigo, ſeparated and precipitated by lime, is made of that colour only by its poſſeſſing a ſmaller proportion of oxygene than the blue indigo?—We might naturally expect, if the difference of colour ariſes from this difference in the proportion of oxygene, that the blue indigo would ſuit beſt for the ſulphate of indigo, becauſe it is to be diſſolved by a farther application of oxygene contained in the oil of vitriol; and this is found to be the caſe, as was lately obſerved: and on the other hand we ſhould ſuppoſe the

copper-

copper-coloured indigo to be beſt ſuited for the indigo vats and for the topical blue, becauſe in theſe the diſſolution is effected by taking away oxygene; and the leſs there is of it, the more eaſily will this be effected; and here alſo the choice and practice of the dyers accords with this hypotheſis, as they conſtantly employ the copper-coloured indigo for theſe laſt purpoſes.—But though the *blue* indigo of Guatamala is the lighteſt and moſt valuable, becauſe its colouring particles are not intermixed with lime, and are but in a ſmall degree mixed with other matters which might give it weight and bulk without contributing to its tingent powers, yet this is not the caſe with all *blue* indigo; for in moſt countries it is now an invariable practice to precipitate indigo by lime-water; and as a deſire to extract as much of it as poſſible from the plant, very frequently induces the operator to carry its fermentation in the ſteepers too far, by which the colouring matter acquires an undue portion of oxygene, ſo as afterwards to appear blue, even when precipitated by lime-water; and as this matter is moreover debaſed by being mixed with other vegetable ſubſtances, extracted from the indigo plant by too much fermentation without affording colour, it happens that indigo of very inferior qualities often appears blue.

Bergman, Quatrenere, &c. have endeavoured by analyſis to aſcertain the component parts of indigo; and M. Berthollet has given a ſufficient account of the reſults of their operations; from all which, corrected by more recent diſcoveries, it appears, that pure indigo conſiſts of a conſi-

derable

derable portion of hydrogene, a little azote, about one-thirtieth of its weight of iron, a very large proportion of the basis of charcoal, and a considerable one of oxygene; which last, I conceive, in these operations to have become united to the carbonic basis, and to have converted it into charcoal. M. Berthollet ascribes the permanency of the colour of indigo to its abundance of charcoal; and he clearly exposes the error of those who have attributed its colour to the very small portion of iron contained in it. The stability and difficult solubility which the colouring matter of indigo acquires by combining with oxygene, seem to resemble, though in a less degree, what the basis of charcoal acquires by a like combination; but in this last the oxygene is so much more intimately combined, that it cannot be separated by the means which separate the oxygene from indigo, in making the topical blue, as I have found by repeated trials upon charcoal, and therefore it can only be acted upon in the last of the two ways of dissolving indigo; I mean by the farther application of vital air, so as to convert it into carbonic acid gas. The first mention of indigo, as known in this country, which I have observed, is in the act of the 23d of Queen Elizabeth, cap. ix. where it is called "*Ancle, alias Blue Inde.*"

The Genipa Americana, Linn. is a very widely-branching lofty tree, growing spontaneously in different parts of Guiana and Brasil, where it is known by different names; in Surinam by that of tapouripa; in Demerary by the name of

launa;

launa; and in Brafil, according to Marcgrave and Pifo, by the names of janipha, janipaba, &c. It bears a fruit nearly oval, of the fize of a large lemon, covered with a greenifh afh-coloured fkin. This fruit, when ripe, affumes very nearly the appearance and texture of a ripe medlar or a baked apple; and being replete with a moderately acid juice, is fometimes eaten to quench thirft. The fubftance of this fruit, while unripe, is hard, colourlefs, and fomewhat bitter; and when cut open there is found in the centre of it a number of feeds in a fmall cavity, furrounded by a foft pulp, the furface of which has a flight blue tinge, probably occafioned by air collected in the cavity where the feeds are placed. Being at Surinam in the year 1770, I took fome of this pulp, and preffing the clear colourlefs juice upon pieces of white linen and cotton, I found that, though the fpots wetted therewith at firft fhewed no colour, yet being hung up to dry, in lefs than twenty-four hours they had acquired a deep ftrong blue, very much refembling that dyed with the ifatis or woad. This blue I tried in vain to difcharge, or even weaken, by a multitude of wafhings with foap and water, by the application of lemon juice, and by long expofure to fun, air, rain, &c. in a climate where at leaft the firft of thefe agents exerts the moft powerful action upon colours; and by repeated trials I convinced myfelf that the blue obtained from this fruit, even by the moft fimple topical application of it, was as permanent as any obtained from the indigo plant.

This blue has long been ufed by the favages of Guiana, Brafil, &c. for painting their fkins of of a dark blue or violet colour, as (according to Cæſar) the woad was uſed by the ancient Gauls and Britons for the ſame purpoſe. During my firſt reſidence in Guiana, in the years 1763, 4, 5, and 6, I had often obſerved the native inhabitants of that country ſtaining their bodies with this colour, which was uſually contained in calabaſhes or gourds, in which they had previouſly macerated the fruit of the genipa, or its pulp, with water for ſome days before. I had myſelf ſtained my fingers with it, and found that I could not remove the colour in any degree by waſhing, though after nine or ten days it gradually diſappeared, doubtleſs by an abraſion or wearing away of the ſubſtance of the cuticle to which it adhered; but at that time I did not attend much to the manner in which this happened, and ſuffered myſelf to adopt an opinion generally prevailing in that country, that this colour would in all caſes ſpontaneouſly diſappear at the end of eight or nine days; an opinion which had been propagated by Cluſius, Piſo, Marcgrave, Hernandez, Rochfort, and others; and which muſt, as I am now perſuaded, have originated from the circumſtance of its uſual diſappearance at thoſe periods when applied to the human ſkin, by an abraſion thereof.

It was not until my ſecond viſit to Guiana that I firſt thought of the application of this blue to the purpoſes of dying and callico printing; and though I did not then remain long in that country, and had no opportunity of ſeeing this blue prepared or applied by the ſavages, who have much leſs intercourſe with the inhabitants of Surinam (where I alone reſided) than with any

of

of the neighbouring colonies, I made a ſuffi-cient number of experiments to aſcertain, be-yond all poſſibility of miſtake, that the fruit of the genipa affords, not a fugitive colour, as had been and probably now is univerſally believed, but a ſtrong permanent blue ſimilar to that of indigo, both in its nature and in the means by which it becomes viſible; I mean by the ab-ſorption of oxygene: and when I conſider the magnitude of the genipa tree, together with the quantity and ſize of its fruit, I cannot help think-ing that plantations of it would prove highly beneficial, on account of the blue dye which the fruit would afford, either in the form of indigo by maceration, &c. or when gathered, cut, and dried, ſo as to prevent putrefaction, and admit of their conveyance to Europe. A gentleman of character and fortune, who reſided ſome time in Bengal, and was the proprietor of a large eſtabliſhment for callico printing in that coun-try, being returned from thence about three years ſince, favoured me with a piece of indigo of a very good quality, which he aſſured me was obtained from an Eaſt Indian tree, one of the leaves of which he at the ſame time ſhewed me; and from its appearance, as well as from other circumſtances, I have very little doubt but it is of the ſame ſpecies as the Genipa Americana; more eſpecially, as there is a tree growing plen-tifully on the coaſt of Malabar, and deſcribed in the Hort. Malabar. by the name of panitsjica-maram, which appears in every reſpect to re-ſemble the genipa, excepting that the authors of that work have omitted the mention of any co-louring property in the fruit of the Malabar tree, an omiſſion which may have proceeded from ſe-veral cauſes.

During my laſt ſhort viſit to Guiana, I did not find any of the fruit of the genipa perfectly ripe, and my experiments were neceſſarily made only upon thoſe which, though they had nearly attained their full growth, were hard and apparently colourleſs. Whether the ſoft juicy pulp of the ripe fruit is more or leſs effectual than the pulp of the unripe fruit for giving colour, I know not; nor do I recollect whether the ſavages of Demerary and Eſſequebo, in preparing this colour, macerated the pulp of the ripe or the unripe fruit for that purpoſe. I have, ſince my return to Europe, been informed that the bark and leaves of the genipa tree, by maceration, afford a blue like that of the fruit. Should this prove true (which ſeems probable), it would doubtleſs render the cultivation thereof very profitable.

Hogs and other animals, feeding upon the fruit of this tree when it falls ſpontaneouſly on the ground, are ſaid to have their bones ſtained with its colour, as happens to animals feeding upon madder, and ſome other colouring matters.

Mr. Martin Liſter (in the VIth Vol. of the Philoſophical Tranſactions, page 2132,) mentions that " the ſeed huſks of glaſtum ſylveſtre, " old gathered and dry, being diluted with wa-" ter, ſtain a blue, which upon the affuſion of " lye ſtrikes a green, which green or blue, be-

" ing touched with the oil of vitriol, dyes a pur-
" ple; and all theſe colours (ſays he) ſtand."—
He adds, that " on the tops of the fungus tube-
" loſus (ſo called by Mr. Wray in his Catalogue
" of the Plants of England), are certain red
" knots, which, upon the affuſion of lye, will
" ſtrike a purple, and ſtand." The juice of ſome of the muſhrooms alſo becomes blue when expoſed to atmoſpheric air. The ſame effect, according to Sennebier, happens to the milky juice of the tithy malus (euphorbia, Linn.).

It is mentioned ſomewhere in the Swediſh Memoirs, by Cronſted, that the ſtalks of the polygonum fagopyrum, Linn. by fermentation in water, afford a blue which did not change either by acids or alkalies.

Brown, in his Hiſtory of Jamaica, p. 143, obſerves, that " the pulp of the berries of the
" randia aculeata, Linn. (called in that iſland
" the indigo berry, and which generally grow
" very numerous on the ſmaller branches of the
" plant), is very thick, and ſtains paper or
" linen of a fine fixt blue colour. I have tried
" it (continues he) on many occaſions, and
" have always obſerved it to ſtand, though
" waſhed with either ſoap or acids; but it does
" not communicate ſo fine a colour with heat.
" It would prove (he adds) an excellent fixt
" blue in all manner of paints and prints, if it
" could be obtained in any quantity; but the
" berry is not very ſucculent, and the people as
" yet are not very induſtrious in theſe parts."
Having had no opportunity of trying the effects or properties of theſe berries, I can only recom-
mend

mend them to the notice of others, which they ſeem to deſerve.

The gentleman who favoured me with a ſpecimen of indigo, obtained from an oriental tree, which I concluded to be that called panitsjica-maram in the Hort. Malabar. as mentioned at page 141 of this volume, gave me alſo a very ſmall piece of a hard green ſubſtance, which had been ſent to him from ſome part of the Eaſt Indies, and which he called a Green Indigo. Upon ſeeing it, I flattered myſelf with a hope of its proving to be what the late Monſ. de Poivre mentions in a little work, publiſhed under the title of "Voyages d'un Philoſophe," &c. as obtained by the inhabitants of Cochin China from a plant called *tſai*, which, when macerated and fermented like indigo, yields a *green* fecula, capable of dying a fine, as well as a laſting emerald or green colour. The quantity of this green ſubſtance thus put into my hands, was much too ſmall even for a ſingle deciſive experiment. I however divided it into three parts. One of theſe I put into boiling water, which appeared to have no action upon it; but it was afterwards diſſolved by a little oil of vitriol like common indigo, producing, however, a green, inſtead of a blue colour. A ſecond of theſe parts I diſſolved with a little cauſtic alkali and orpiment, in order to ſee whether, excepting the difference of colour, it would poſſeſs properties ſimilar to thoſe of indigo when diſſolved by the ſame means, and like the latter be able to produce a fixed colour on linen or cotton by topical application. This however it did not ſeem to be capable of doing: the remaining part I put into

a little

a little ſpirit of wine, which diſſolved a portion of it, though very ſlowly; a circumſtance in which it differs materially from indigo, and ſeems in ſome degree to reſemble that green-coloured fecula which ſome plants afford, and particularly the cruciform, when fermented like the indigo plant in warm weather. I confeſs, however, that theſe experiments were made on ſuch very ſmall quantities of the ſubſtance under conſideration, that very little dependance ought to be placed upon them. But this is certain, that if a green colouring matter exiſts, and can be diſcovered with properties in other reſpects ſimilar to thoſe of indigo, it will be a moſt important addition to the Materia Tinctoria.

No ſubſtantive vegetable yellow has been, as I believe, ever employed for dying in Europe, though there are accounts of vegetables, growing in diſtant countries, which ſeem capable of affording ſuch yellows with advantage. Mr. Clarkſon, in his eſſay on the impolicy of the African Slave Trade, relates, that "a gentleman, reſident upon the coaſt, (of Africa,) ordered ſome wood to be cut down, to erect a hut: whilſt the people were felling it (continues Mr. C.) he was ſtanding by, and, during the operation, ſome juice flew from the bark of it, and ſtained one of the ruffles of his ſhirt. He thought that the ſtain would have waſhed out; but, on wearing it again, he found that the yellow ſpot was much more bright and beautiful than before, and that it gained in luſtre every ſubſequent time of waſhing." Pleaſed with the diſcovery, he ſent home a ſmall ſample of the bark, which "produced a valuable yellow dye, *far beyond any other ever in uſe in this country.*"

Mr. Clarkſon adds, that this gentleman "is ſince unfortunately dead, and little hopes are entertained of falling in with the tree again." The colour mentioned in this account, if there be no error in it, muſt have been of that kind which I have denominated ſubſtantive colours, as capable of being fixed by dying, &c. without the aid of any aluminous, or other baſis.

M. du Pratz, in his hiſtory of Louiſiana, alſo mentions a tree, or ſhrub, ſeldom exceeding the thickneſs of a man's leg, the wood of which, he ſays, is yellow, and yields a water of the ſame colour if cut in the ſap. Both the wood and the water, he ſays, have a diſagreeable ſmell; and the former is uſed by the natives for dying, firſt cut into ſmall pieces and boiled in water, into which they dip feathers, hair, &c. He calls it ayac, or ſtinking wood; and as he mentions nothing of the uſe of allum, or any other baſis or mordant, this, if his account be accurate, muſt alſo be a ſubſtantive colour. I fear, however, that the information of perſons, not particularly acquainted with the ſubject, cannot be much relied upon reſpecting the natures and properties of dying drugs.

The roots and bark of the Berberis vulgaris, Lin. afford a yellow to wool without any baſis, but it has not the ſmalleſt degree of permanency againſt the action either of air or ſoap. This

ſhrub

ſhrub indeed furniſhes a remarkable inſtance, to ſhew how little can be diſcovered reſpecting the colouring properties of plants from their external appearances. A ſimilar inſtance lately occurred to me in the wood, bark, and root, of the Zantoxylum clava Herculis, Lin. (the tooth-ach tree, or japan pepper tree,) every part of which is ſtrongly coloured of a moſt beautiful yellow; but having procured ſome of it for trial, I could extract but little colour from it, notwithſtanding its ſeeming abundance of tingent matter; and the little which I did extract, was like that of the Berberis, utterly incapable of forming the leaſt union with any baſis, or of reſiſting the action of air, or of ſoap, in any degree.

The ſeeds of the Bixa Orellana, (growing ſpontaneouſly in different parts of Guiana,) are covered with a reddiſh pulp, which is collected and ſent to Europe in different forms, under the names of annotta, arnotta, and roucou. It is principally employed for dying ſilk, and ſometimes for cotton; though its colour, by all the ways and means of applying it hitherto diſcovered, is ſo fugitive, that perhaps it would be better if it were never employed even for dying ſilk. It partakes ſo much of a reſinous nature, as to diſſolve but very imperfectly in water; and therefore at *leaſt* an unequal weight of pot-aſh is employed to render it ſoluble in that vehicle, and afterwards the ſilk or cotton is dyed therein without any aluminous or other baſis *. The

* The liquid ſold in different parts of the town, under the name of "Scott's Nankin Dye," appears to be nothing but annotta diſſolved by pot-aſh in water.

colour of annotta becomes leſs red, and more inclined to the orange, when ſeparated from the ſeeds by maceration, in water, as is uſually practiſed; and by the addition of pot-aſh, it is made to incline ſtill more to the yellow hue. This laſt change may, however, be readily overcome by adding any of the different acids to the dying liquor, after ſufficient colour has been taken up by the ſilk or cotton dyed therein; though argol or tartar is generally preferred for this purpoſe, becauſe it not only raiſes the colour, but ſeems to render it a little more fixed. It is remarkable, that though the colour dyed with annotta fades very faſt by expoſure to air, it powerfully reſiſts ſoap, and the action of the ſtrongeſt acids. And it certainly affords one, among ſeveral inſtances, of colours which decay by cauſes very different from combuſtion; becauſe linens and cottons dyed in the uſual ways with annotta, and afterwards wetted with oxygenated muriatic acid, inſtead of ſuffering a diminution of colour, were enabled by it to bear expoſure to the weather longer, and with leſs injury than pieces of the ſame dyed linens and cottons, to which none of the oxygenated acid had been applied, as I obſerved on repeated trials: and when we ſee that the colours of indigo and madder, the moſt durable of all thoſe given by the art of dying, are ſpeedily deſtroyed by this oxygenated acid, and that it has no ſuch deſtructive action upon ſome of the moſt fugitive of all dyed colours, (ſuch as that of annotta,) we certainly muſt conclude, that the colouring matter of this laſt ſubſtance is conſtituted very differently from that of madder and of indigo, and ſuſceptible of being preſerved as well as de-

ſtroyed

ſtroyed by very different means. The deſtruction, therefore, of all dyed colours, cannot juſtly be imputed to any ſingle cauſe, be it combuſtion or any other; nor ought we to conſider the oxygenated muriatic acid as acting on colours in the ſame way as air, when one preſerves what the other deſtroys. The freſh pulp of the Bixa Orellana taken immediately from the ſhrub whilſt growing, and applied to cotton without the addition of any alkali, ſeemed to afford a colour more laſting and higher, or more approaching to the red, than what can be dyed from the pulp ſeparated by maceration, as is done in producing the common annotta. The greateſt conſumption of this article, at leaſt in Great Britain, is, in giving a kind of yellowiſh orange to cheeſe, for which it is very ſuitable, becauſe it is harmleſs, and nearly taſteleſs.

The Lawſonia inermis of Linn. has long been uſed throughout India, Perſia, Arabia, Egypt, and in many other parts of Africa, for giving a reddiſh ſtain to the nails, lips, &c. It is the Liguſtrum Ægyptiacum of Proſper Alpinus, and the Hinna of the Arabians. Sir William Jones relates, that being at the iſland of Hinzuan or Johanna, and obſerving a very elegant ſhrub, about ſix feet high, not then in bloſſom, he learned that it was the "Hinna," of which he had read ſo much in Arabian Poems. "Muſa (one of the inhabitants, ſays he) "bruiſed ſome of the leaves, and having "moiſtened them with water, applied them to "our nails and the tips of our fingers, which in "a ſhort time became of a dark orange ſcar-"let."—Nieuhoff ſays, "they prepare the tinc-

"ture by ſteeping the leaves after they have "been rubbed ſmall upon a marble ſtone, in "fair water, mixed with a ſmall quantity of "lime."—"With this (continues he) the "Turks and Perſians alſo dye their horſes' "tails." This ſhrub, according to Adanſon, is called foudenn by the negroes of Senegal, where it is uſed both by the men and women to give their nails a red ſtain, which laſts until the ſubſtance of the nails changes by growth. As the colour of this ſhrub requires no kind of baſis or mordant, it muſt naturally belong to the claſs of ſubſtantive colours.

I lately received a few ounces of ſmall ſeeds, incloſed in a flea-coloured huſk, but without any information reſpecting the plant on which they grew. They were brought from the coaſt of Barbary, where, as I was informed, they are uſed in dying red or pink colours. In two or three ſmall trials which I made with them on ſilk, they appeared to poſſeſs a ſubſtantive colouring matter, ſimilar in ſome reſpects to that of ſafflower. At firſt I thought they might be the ſeeds of the Gardenia florida, which, according to the accounts of Mr. James Cunningham, who formerly travelled into different parts of the Eaſt-Indies in purſuit of natural curioſities, the Chineſe employ for dying *ſcarlet*, under the name of *umki* *. I found, however, that this

* Dr. Plunkenet, in his Amaltheum, page 29. ſays, "Semina tinctoribus inſerviunt iis enim ab indigenis Sinenſibus optime tingitur nobilis ille color, quem *eſcarlatinum* "noſtrates vocant, ut nos monuit vir multiplicis induſtriæ "atque indefeſſi laboris hac in parte, D. Jacobus Cunninghamus."

could

could not be the cafe, as the feeds of the Gardenia grow inclofed, feveral of them in one common capfule, involved in a rich coloured mucilaginous fubftance; whereas the Barbary feeds evidently grow without any fuch inclofure. I cannot difcover whether the feeds of Gardenia ought to be confidered as a fubftantive or an adjective colouring fubftance; all accounts refpecting them being defective.

There are feveral fpecies of *Lichen*, or mofs, capable of producing fubftantive colours of various complections, and of different degrees of durability. M. Weftring appears to have lately made numerous experiments in dying wool and filk with the different moffes which grow abundantly in Sweden. His firft publication on this fubject, in the tranfactions of the Stockholm Society, relates to his experiments on the moffes denominated *Leprofi*. He found ammoniac or volatile alkali to be the moft active diffolvent of their colouring matter: mordants appeared hurtful, as the gummy parts of the moffes did not bear the action of acids. Their colours were various; and fome of them yielded their colouring matters by maceration in cold water only; and thefe were afterwards as capable of being fixed by dying, as thofe extracted by ammoniac. Some of the moffes in this country, (particularly the Lichen petræus purpureus Derbienfis of Parkinfon *,) and many in America, not yet brought into ufe, feem capable of being employed with advantage in dying. But of thefe

* Cork or arcel.

 I fhall

I ſhall ſay more in a future volume; and in the mean time refer my readers to Mr. Berthollet's work for what is at preſent known reſpecting the two ſpecies uſually employed for the preparation of archil. I mean the Lichen roccella, and the Lichen parellus, Linn.

To this claſs alſo belongs the Carthamus tinctorius, or ſafflower; but my own experiments having afforded nothing of importance reſpecting it, I ſhall in like manner refer my readers to Mr. Berthollet for information on this ſubject.

There is a ſpecies of colouring matter diffuſed in greater or leſſer proportions through the barks and other parts of almoſt all trees and ſhrubs, and which, without any baſis or mordant, permanently dyes or ſtains wool, ſilk, cotton, and linen, of that particular kind of colour which the French call "fauve," (fawn-colour,) and ſometimes couleur de racine, ou de noiſette, (root, or hazel-nut colour.) This being naturally blended with ſome of the more valuable colours of vegetables, frequently does harm, by degrading or obſcuring them. It is found moſt abundantly in the peeling or huſks of walnuts, (Juglans regia,) in the roots of the walnut-trees, in alder, bark, &c.; and it ſeems to acquire both body and permanency by attracting and combining with the baſis of pure air. Mr. Berthollet has, however, treated ſo fully and ſo well of the properties of this kind of colouring matter, when applied ſubſtantively, that I cannot do better than refer my readers to that part of his

his work which relates to it; obſerving at the ſame time, that the colouring matter in queſtion, though capable of being permanently fixed without any metallic or earthy baſis, does however, in ſome inſtances, acquire new and more uſeful properties when applied with a baſis adjectively, which I ſhall more particularly notice hereafter under the proper heads.

There are three ſpecies of poiſonous ſhrubs or vines growing in North America, and containing in their ſtems, leaves, &c. a white milky juice, which when applied to linen, cotton, or ſilk, produces a ſtain, which ſoon becomes of a full, ſtrong, lively, and durable *black colour*, incapable of being diſcharged by repeated waſhings, or impaired by the weather. Theſe are the Rhus vernix, (growing likewiſe in Japan;) the Rhus radicans; and the Rhus toxicodendron, Linn. Some trials which I formerly made in America ſeemed to indicate the laſt of theſe as affording the deepeſt and moſt permanent black. But in all of them this colour probably depends on the addition of oxygene to the colourable matter; an addition which, in the formation of indigo, produces only a blue, whilſt in the preſent inſtance it changes a white milky juice to the greateſt poſſible extreme, by rendering it of a full ſtrong black.

The fruit or beans of the Avicennia tomentoſa, Linn. called Malacca beans, or marking nuts, have long been uſed in the Eaſt-Indies for marking upon cottons, &c. They contain each a ſmall kernel, ſurrounded by a viſcid blackiſh juice, which in ſome that were lately given to me, me, by a gentleman who had been poſſeſſed of them near ten years, very much reſembled tar, both in colour and conſiſtence; though it ſeems probable that in the freſher beans the juice is more fluid, and of a lighter colour. Having extracted ſome of this juice, I applied it topically to a bit of white callico, which it penetrated thoroughly, and being ſuffered to dry, it was both waſhed and boiled in ſoap ſuds, and afterwards expoſed to the weather for the ſpace of two months, during which time it had become decidedly black, (probably by attracting oxygene;) but as the juice had been at firſt ſo thick and viſcid, it ſeemed more like a painted than a proper dyed or ſtained colour. Oſbeck ſays, that in uſing theſe beans, the letters or marks ſhould be covered, while wet, with quick lime, which enables them to bear waſhing, and prevents the juice from hurting the ſtuffs marked with it. Whether lime be neceſſary for theſe purpoſes may, I think, be doubted, ſince, though I uſed none, the colour was not weakened by waſhing, nor did the cotton appear to have received any injury: and reſpecting any injury to the ſtuffs, this was an effect which ſeemed of all others the moſt unlikely, as the juice in queſtion, which I taſted, had not the ſmalleſt degree of acrimony.

Kœmpher (Am. p. 739.) has improperly called this "Anacardus Orientalis;" it being a pod-bearing tree, very diſſimilar to the true anacardium or caſhew nut, which alſo affords a juice capable of giving a laſting brown ſtain to linens and cottons. Several other vegetables produce effects of the ſame kind, but they either do do it so sparingly, or the colours they afford are of so little value, as to deserve no particular notice.

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## CHAP. VI.

### *Of Mineral Substantive Colours.*

"Rien n'est plus facile dans les sciences fondées sur l'ex-
"perience que de multiplier les faits particuliers,
"mais ces faits ne sont dignes d'attention, que
"l'orsqu'ils servent a conduire a des vérités géne-
"ralés, ou que presentant au contraire, des singu-
"larités nouvelles & imprevus, ils deviennent un
"objet de recherches." HIST. de l'ACAD. R[e], &c. 1777.

EACH of the metals and semimetals is capable, when dissolved, of becoming a basis or mordant, for fixing and modifying some at least of the different adjective animal or vegetable colouring matters, with more or less advantage, by dying. But besides this property, which will be made a subject of future consideration, several metals and semimetals, or rather their solutions or oxides, are capable of being united and fixed directly in the fibres of linen, cotton, silk, and wool, and of thereby producing various permanent substantive colours. It is indeed true, that hitherto but few metallic preparations, excepting those of iron and copper, have been used in this way, or for this purpose; I mean that of giving substantive colours.

Iron,

Iron, by whatever means diſſolved, poſſeſſes ſo much affinity to linen and cotton, that when applied to them its oxide or calx decompoſes and fixes itſelf permanently in their fibres, and thereby produces colours differing conſiderably from each other, according to the different ſtates in which the oxide may have been applied, particularly in reſpect of the portion of oxygene combined with it. But as the oxide of iron, in *all ſtates*, and *however obtained*, is ſtrongly diſpoſed to attract the oxygene of the atmoſphere, its different colours, by this addition, ſoon loſe their peculiar ſhades or variations, and acquire the ruſty colour of what is commonly called *iron mould*. This addition, moreover, ſoon renders the oxide in ſome degree corroſive, and joined perhaps to the rigidity which it occaſions by concreting in the fibres of wool, ſilk, cotton, and linen, it diſpoſes them to become feeble, or, as it is commonly expreſſed, *rotten*. There are few, if any, who have not obſerved inſtances of this effect from ſpots of what is called iron mould on linens, &c. which produce holes, long before any appear in other places. But where iron is uſed in dying, merely as the baſis of animal or vegetable colouring matters, theſe laſt, by combining with its particles, leſſen their diſpoſition to attract oxygene, and by keeping them farther aſunder, ſo far prevent their concretion, as in a conſiderable degree to obviate the rottenneſs in queſtion; though there is but too much reaſon to fear, that even in this way ſtuffs dyed with a ferruginous baſis or mordant, are the leſs durable from that circumſtance, and that it is from the uſe of this metal that the rotten-

neſs

ness so generally complained of, as accompanying the black dye, principally results.

The use of what is commonly called iron liquor, (acetite of iron,) made by dissolving that metal in vinegar, alegar, &c. is well known both as a mordant or basis for black, purple, drab, and olive colours, &c. in callico printing, and also as a topical substantive colour or stain for application by the block and pencil in callico printing. This latter use of it, however, cannot be too much discouraged, for the reasons already alleged.

Lately, the acid of tar has been employed in this country to dissolve iron, and produce an iron liquor, which is used by callico printers, to give a substantive topical stain of a darker brown than what the common iron liquor produces. A similar effect may be produced by combining arsenic with the oxide of iron; but no benefit can result from this, equal to the danger of putting that poisonous drug into the hands of careless, and sometimes ill-disposed people.

At Manchester, substantive buff colours are dyed with a diluted solution of iron, by the nitric acid; first neutralizing it by an addition of pot-ash, and taking care, after the dying is performed, to wash off all the loose or superfluous particles of iron, that it may not injure the cottons by an excess in quantity. But the colour dyed in this way is certainly accompanied with some degree of rottenness, from the causes before mentioned, and liable to other inconveniences,

veniences, particularly that of turning black, if accidentally wetted by tea, &c.

Iron diſſolved by muriatic acid, affords a greeniſh-coloured ſolution; and this being applied to linens and cottons, the iron fixes itſelf, and attracting a conſiderable portion of oxygene from the atmoſphere, produces a very fine yellow ſtain. But a ſingle waſhing deſtroys this beautiful yellow, (which depends wholly upon the union of muriatic acid, oxygene and iron,) and reduces it to the common ruſty iron mould colour. Indeed this defect, as has been already mentioned, attends all the preparations of iron, however various their colours may be, at firſt; and therefore, as well as in conſideration of the rottenneſs which they occaſion, when applied ſubſtantively to linens and cottons, I am much more inclined to diſcourage their uſe in this way, than promote it by any farther explanations.

The uſes of copper, as a baſis in dying adjectively, will fall under our conſideration hereafter. At preſent I have only to mention its properties as a ſubſtantive colouring ſubſtance. The ſolutions of this metal readily unite to the fibres of linen and cotton when applied to them; and being ſo united, whatever may have been their original colours, they ſpeedily attract oxygene from the atmoſphere, and are thereby rendered green; a colour which, when produced in this way, is ſufficiently durable upon linen and cotton, ſo far as reſpects the impreſſions of air; but, when waſhed with ſoap, the oxide of copper is readily diſengaged from the linen or cotton, and combining with the ſoap, which it curdles, ſeems to form with it a kind of green paint.

In this reſpect, however, the ſolution of copper by ammoniac, (volatile alkali,) differs I believe from all the other ſolutions of that metal; for when it is applied to linen or cotton, though by abſorbing oxygene it ſoon loſes its fine blue colour and becomes green, yet ſoap in waſhing does not ſeparate or diſcharge the ammoniated calx, except by very ſlow degrees; ſo that, with care, it will reſiſt a great number of waſhings without much diminution of its colour; and as it ſuffers nothing from the action of air, I think it might be advantageouſly employed, particularly on fine muſlins, as affording a *very delicate* though *pale* ſubſtantive green, and eſpecially ſince in this way it may be applied ſo very readily and conveniently. Water ſhould be made to diſſolve as much ammoniac as it can for this purpoſe, and the ſolution ſhould be fully ſaturated with copper; after which it muſt be ſufficiently thickened with gum, and kept in bottles, cloſely ſtopped, pouring it out by a little at a time when wanted for penciling. I have ſometimes thought the colour ſomewhat improved, when, inſtead of diſſolving copper in its metallic ſtate, I diſſolved the nitric calx of that metal by volatile alkali; but at other times this ſuppoſed improvement has appeared doubtful.

Subſtantive copper-greens have ſometimes been dyed from ſulphate of copper with lime and ſoap ſuds, employed ſo as to precipitate the particles of copper upon the ſtuffs intended to be dyed; but the colour given by theſe means

is

is ſo fugitive, that it deſerves no farther notice.

There are ſeveral of the other metals and ſemimetals which, when precipitated or depoſed upon animal and vegetable ſubſtances, in a kind of middle ſtate between the metallic and the oxidated, combine therewith, and produce very durable ſubſtantive colours. To effect this precipitation, it is neceſſary that the ſeveral metallic oxids ſhould be deprived of a conſiderable part of their oxygene; and this happens to them more readily, when applied to wool, (from its animal nature,) than when applied to ſilk; and when applied to the latter, (from its mixed nature,) more readily than if applied to linen and cotton. But vegetable ſubſtances are eaſily rendered capable of producing this effect, by firſt impregnating them with either animal, alkaline, or inflammable matters; for which reaſons will readily occur, after what has been heretofore ſo often explained. In theſe caſes, light frequently concurs with the matters laſt mentioned, to haſten a ſeparation of the oxygene. Hallot obſerves *, that characters traced on writing-paper with a diluted nitro-muriate of gold, began after a few hours expoſure to the air, (he probably ſhould have ſaid light,) to manifeſt colour, and ſoon after became of a very dark violet—" violet " forcé preſque noir." But when ſhut up in a cloſe box, he ſays, the writing did not become viſible during ſeveral months. And he adds, that the like happened to characters written with a diluted nitrate of ſilver, though they became very viſible in the ſpace of an hour when ex-

* Mem. de l'Acad. R. &c. 1737.

poſed to the ſun's rays. See Mem. de l'Acad. R$^{e}$ des Scien. de Paris, 1737.

Dr. Brugnatelli (Ann. de Chymic, tom. iii.) alſo mentions, that characters written with a ſolution of gold become of a fine purple when expoſed to the vapour of ſpirit of wine (which deprives them of oxygene), and of a deep red colour in the hepatic or ſulphureous inflammable air.

Every one who has had much occaſion to handle the nitro-muriatic ſolution of gold, will probably have found his fingers ſometimes ſtained with it of a fine reddiſh purple colour. This has happened to mine very often, and nothing but the wearing off or abraſion of the ſkin would ever remove it. By impregnating linens, cottons, and ſilk, with animal, inflammable, alkaline, and ſome other matters, they are enabled to receive fine durable purples by the like ſolution. The yolk, as well as the white of egg, having been beat up with water and a little ſugar, I ſoaked ſome muſlin therein, and when dry, applied a diluted nitro-muriate of gold to it, topically, which produced a very fine ſtrong purple. Cotton, impregnated with lintſeed oil, received from the like application a ſtrong violet colour, as it did when impregnated with ſoda, and acidulous arſeniate of pot-aſh (Macquer's arſenical neutral ſalt): being impregnated with ſoda, ſulphure of pot-aſh, and ſugar, the cotton received an olive brown by the ſame application; and a blackiſh brown, when impregnated with alcohol and liver of ſulphur. Having ſoaked cotton and ſilk in a diluted muriate of

M tin,

tin, I plunged them into water which contained a little powdered chalk, and preffing out the water, dried them; this being done, I applied to them topically, by the pencil, a diluted nitro-muriate of gold, which produced, wherever it was applied, a ftrong lively purple colour, apparently of a very durable nature. This effect is fimilar to that which takes place when the folutions of gold and tin are mixed together, and the metallic oxides having a ftronger attraction for each other than for their acid folvents, unite, and, by reafon of their gravity, precipitate together in the form of a purple powder, which confifts of both of thefe oxides, though the colour is wholly owing to that of the gold.

Leeuwenhoek mentions (Philofoph. Tranfact. Vol. xxiv.), that by touching nitrate of filver, his fingers were ftained black; and that finding it impoffible otherwife to remove the ftain, he cut off and burnt the fkin, and then examining it by a microfcope, he found the filver revived in a multitude of little globules.—“I have lying on my defk (continues he), a linen handkerchief, which was ftained with aqua-fortis, “impregnated with filver, with a large black “fpot about as large as a fhilling;” and he adds, that having ineffectually tried to difcharge the colour by fix wafhings, and by laying the handkerchief out to bleach, he cut out the ftained part, burnt it to coal, and viewing it by a microfcope, faw thoufands of fine filver globules therein. The effect here mentioned to have been produced upon the fkin, accords with that which folutions of filver are known to produce in blackening hair, and other animal fubftances;

ſtances; but in reading this account, I thought it extraordinary that clean linen, impregnated with no animal, inflammable, or alkaline matter, ſhould ſo far deprive nitrate of ſilver of its acid, as to produce the effect deſcribed; and I repeated the experiment ſeveral times without ſucceſs. At length, however, I took a ſilver tea-ſpoon, which had ſtood half filled with aqua-fortis for ſeveral weeks, and which on the hollow inſide was become almoſt black by it, and by the oxygene of atmoſphere which it had attracted, and having poured out the more fluid part of the ſolution, I rubbed a bit of cambric againſt the wet oxidated hollow ſurface, and hanging it up for a few days in the open air, on the ſunny ſide of a wall, I found the cambric permanently ſtained of a very dark violet colour. A fine piece of cotton, however, by the ſame means received but a very ſlight diſcoloration. Though cotton, when impregnated with ſoda and the acidulous arſeniate of pot-aſh, received a ſtrong durable ſlate colour by being touched with diluted nitrate of ſilver; a drab colour by the ſame means when impregnated with ſoda and ſugar; a dark olive brown, with ſulphure of pot-aſh (liver of ſulphur), and ſpirit of wine; the ſame with ſoda, liver of ſulphur, and ſugar; and being impregnated with white of egg, beat up in water with ſugar, the cotton received from the nitrate of ſilver a very ſtrong browniſh black; and when cauſtic vegetable alkali was added, it became a little blacker. The yolk, inſtead of the white of egg, produced nearly the ſame effect. All theſe colours were often waſhed, and expoſed for a long time to the weather, without being changed.

The oxides of mercury very eaſily give up their oxygene, and therefore they are readily precipitated by the means before mentioned upon vegetable as well as animal ſubſtances, affording generally either black or dark colours, though of but little permanency, becauſe the reſidue of their oxygene ſoon ſeparates, and the mercury recovers its fluid metallic form. Nitrate of mercury applied to cotton, which had been impregnated with ſoda, produced at firſt a yellow, which ſoon changed to an olive, and being waſhed with ſoap, to a full black colour; but after a few days expoſure in the open air, it almoſt entirely diſappeared. On cotton, impregnated with ſoda and ſulphure of pot-aſh, it immediately produced a black, which, by waſhing and expoſure in open air, changed in about ten days to an olive, and ſoon after diſappeared. On cotton, impregnated with ſulphure of pot-aſh and ſpirit of wine, it alſo produced a black, which diſappeared like the former; and with cauſtic vegetable alkali it produced nearly the ſame effect. With orpiment, diſſolved by pot-aſh, it produced a very *deep black*, which ſtood two or three weeks expoſure to the weather; after which the mercury began to revive, and the colour to diſappear in ſpots.

Nitro-muriate of Platina, applied to cotton and ſilk, impregnated with ſoda; with ſoda and liver of ſulphur; with ſoda and the acidulous arſeniate of pot-aſh; with orpiment diſſolved in pot-aſh; with liver of ſulphur and alcohol; and with lintſeed oil, ſeverally, produced various purples, olives, dark and reddiſh browns, moſt of which appeared ſufficiently durable.

Nitrate

Nitrate of cobalt applied to cotton, impregnated with ſoda; with ſoda and acidulous arſeniate of pot-aſh; and with cauſtic vegetable alkali, produced lively pink and roſe colours, which ſtood waſhing and expoſure to weather for a conſiderable time.

The oxide of cobalt, diſſolved by muriatic acid, and applied to cotton impregnated with ſoda, when held to the fire exhibited the moſt beautiful green, which, as the cotton cooled, changed to an apple-green; then paſſed through all the ſhades of yellow, and became a kind of pale buff colour, which the oxide retained after the cotton had been waſhed with ſoap; but then on being heated, it was found to have loſt the property of becoming green, though on dipping it into a diluted muriatic acid, it immediately regained and exhibited the ſame property. Theſe effects are connected with thoſe which ſimilar ſolutions of cobalt produce as ſympathetic inks; though I confeſs myſelf diſſatisfied with all the explanations hitherto given of them. Perhaps I may offer another hereafter. The preſence of muriatic acid is eſſential to their exiſtence, the nitrate of cobalt producing no ſuch phenomenon; nor did I find that the preſence or abſence of light had any effect in retarding or promoting any of the changes of colour here mentioned.

The nitrate of nickle applied to cotton impregnated with ſoda and ſugar, produced a green, but not ſufficiently durable to be of any uſe in this way.

Nitrate of manganefe by fome of thefe impregnations produced different browns, which feemed to poffefs confiderable permanency.

I could add the refults of feveral other applications of this fort, but at beft they would only prove to be what Bacon Lord Verulum has termed *Experiments of light rather than of fruit*; and indeed this may be the cafe with many of thofe which I have juft related. It would not, however, be the cafe of thofe which regard the application of gold as a fubftantive colour, if the dearnefs of that metal were not an obftacle to its ufe in this way; fince the beauty of its purples and violets, and the facility of applying them topically and permanently by the pencil to fine muflins, filks, &c. would otherwife render them very defirable and ornamental. It is doubtlefs on principles fimilar to thofe before mentioned, that fome compofitions which afford very durable black colours for marking on linen, &c. are now made and fold in London. Soda, diffolved and thickened by a little ifinglafs, or fome animal mucilage or glutinous matter, is probably firft applied, and, when dried, names or letters are written thereon, with a pen dipped in particular metallic folutions.

In the firft Volume of Ann. de Chymie, Mr. Berthollet obferves, that the fimple mixture of oxide of lead with lime, blackens wool, hair, nails of animals, and white of egg, but not filk, nor fkin, nor the yolk of egg, nor animal oil; and that fome perfons ufe this mixture to render white or grey hairs black, firft flackening the lime. To

try

try its effects in dying, I boiled flannel in lime-water with litharge, and found that it took a pretty full black, which stood washing with soap and exposure to the weather. Strong acids dissolved the lead, and changed the colour; but the application of vinegar did not seem to do so. The lime, however, weakened the texture of the wool considerably, as he has also observed. Whether this evil can be avoided by using it more sparingly, I have not yet ascertained. I found the mischief greatly increased by adding orpiment, which seems to produce a similar effect in those depilatory compositions first brought to Europe from Turkey.

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## CHAP. VII.

### *Of Adjective Colours generally.*

"Les faits sont de tous les temps, ils sont immuables, "comme la nature dont ils sont le langage; mais "les consequences doivent varier selon l'etat des "connoissances acquises."

CHAPTAL *Elemens de Chimie.*

ALL adjective colours owe their durability, and frequently their particular complections, as well as their lustre, to the interposition of some earthy or metallic basis; which, having a considerable attraction both for the colouring matter, and the fibres of the stuff about to be dyed, combines with and serves as a bond of union between them. These earthy and metallic substances, having been usually employed in a ſtate of ſolution or combination with acids, were from that circumſtance denominated *mordants* (biters or corroders) by the French, who indeed began to employ the term long before any thing like a true theory of dying had been conceived; whilſt even allum was ſuppoſed to act by its ſulphuric acid, and not by the pure clay upon which its uſefulneſs depends, and whilſt in truth all the other matters called mordants were ſuppoſed to be uſeful only by their ſolvent or corroding powers; and the term having been thus introduced, has been ſince adopted in other countries. The ingenious Mr. Henry of Mancheſter has, however, lately objected to it, with great reaſon*, and propoſed in its ſtead to employ the term *baſis*, a term which ſeems defective only in as much as it does not expreſs that particular *affinity*, or *power of attraction*, which manifeſtly ſubſiſts between theſe earthy and metallic ſubſtances, and the ſeveral adjective colouring matters, as well as between the former and the fibres of wool, ſilk, cotton, &c. I confeſs, however, that no other leſs objectionable term has occurred to me; and being unwilling to propoſe new terms, without ſome cogent reaſon, I ſhall employ both the term of mordant and that of baſis; though not indiſcriminately, in all caſes at leaſt, ſince I ſhall generally uſe the former to ſignify theſe earthy and metallic ſubſtances, when actually diſſolved by ſome acid, alkaline, or other ſolvent, and when of courſe they will commonly prove more

* See his "Conſiderations relative to the Nature of "Wool, Silk, and Cotton, as Objects of the Art of Dy-"ing, &c." in the third Vol. of the Memoirs of the Mancheſter Society.

or

or lefs corroding or biting, according to the original meaning of the term. But the denomination of bafis will moft frequently be employed to defignate the fame earthy and metallic fubftances, diftinctly and feparately from any acid or other folvent, either in relation to their properties, when actually fixed in the pores or fibres of wool, filk, &c. or when it is not intended to notice any property which may more immediately refult from their combinations with any particular menftruum. Mr. Berthollet indeed gives the term mordant a much more extenfive fignification, as meaning all the different chymical agents capable of ferving as *intermedia*, between the feveral colouring particles, and the ftuffs to be dyed with them, either for the purpofe of affifting their union, or of modifying it *. This laft effect (of modification) may, however, be produced by a variety of matters befides thofe which are of the earthy or metallic kinds, and indeed by every thing capable, not of fixing, but of varying only, the fhades of adjective colouring matters. Thefe, therefore, I think it more proper to defignate, not as mordants or bafes, but as *alterants*, whofe ufe and application may in this refpect be extended to fubftantive as well as to adjective colours.

The true natures and ufes of mordants or bafes for the purpofes under confideration, can,

* "L'on donne le nom de mordant aux fubftances qui "fervent d'intermedes entre les parties colorantes & les "etoffes que l'onteint foit pour faciliter leur combinaifon, "foit pour la modifier." *Elemens de l'Art de la Teinture*, tom. i. p. 26.

I be-

I believe, in no way be ſo diſtinctly manifeſted, or ſo clearly illuſtrated, as by their effects in what I ſhall call *topical* dying, or that ſpecies of it by which different colours are communicated to particular ſpots or figures, on the ſame piece of cotton or linen, according to the ſeveral baſes previouſly applied thereto, and which principally conſtitutes that truly wonderful art, the art of callico-printing. I ſhall therefore in this place bring under my reader's notice ſome of the more important operations of that art, reverting at the ſame time, as far as we can, towards its remote origin, in order to ſee how and by what means it has attained its moſt important improvements.

Pliny deſcribes the Egyptians as practiſing a ſpecies of topical dying, or callico-printing, which, as far as can be diſcovered from his general terms, appears to have been ſimilar to that which, many ages after, was found to exiſt in Hindoſtan and other parts of India, and was from thence introduced into this and other countries of Europe. He ſays, the Egyptians began by painting or drawing on white cloths, (doubtleſs linen or cotton,) with certain drugs, which in themſelves poſſeſſed no colour, but had the property of attracting or abſorbing colouring matters. After which, theſe cloths were immerſed in a heated dying liquor, and though they were colourleſs before, and though this dying liquor was of one uniform colour, yet when taken out of it ſoon after, they were found to be wonderfully tinged of different colours, according to the different natures of the ſeveral drugs

drugs which had been applied to their different parts; that thefe colours could not be afterwards difcharged by wafhing, &c.*

Whether the Egyptians borrowed this wonderful art from the Hindoos and other inhabitants of India, or whether the latter borrowed it from the Egyptians, is a queftion which probably may be anfwered without much difficulty, if we confider the many reafons which there are for believing that this art has been practifed over the greateft part of India during a long fucceffion of ages; that not only the art itfelf fubfifted there, but that the colouring, and other materials for exercifing it, were the natural and peculiar productions of that country rather than of Egypt; that the Indians were highly civilized at leaft twenty-two centuries ago, during which fpace of time their manners, fanctified (if I may fo exprefs myfelf) by being connected to their religion, fuffered little, perhaps no change; and their trades were carefully perpetuated in particular families; and alfo that among thefe their manufactures were undoubtedly of very great antiquity, whilft obvious ways, by which they

* "Pingunt et veftes Ægypto inter pauca mirabili genere, candida vela poftequam attrivere illinentes non coloribus, fed colorem forbentibus medicamentis. Hoc cum fecere non apparet in velis fed in cortinem pigmenti ferventis merfa, poft momentum extrahuntur picta. Mirumque cum fit unus in cortina colos, ex illo alius atque alius fit in vefte accipientis medicamenti qualitate mutatus. Nec poftea ablui poteft. Ita cortina non dubia confufura colores fi pictos acciperet, digeret ex uno, pingitque dum coquit. Et aduftæ veftes firmiores fiunt quam fi non urerentur." PLINII, l. xxxv. fect. 42. fol. 789.

might

might have been eaſily extended to Egypt, and other countries, undoubtedly exiſted long before the time when Pliny wrote.

Major Rennell obſerves, that "a paſſion for "Indian manufactures and products has actuated "the people of every age, in lower Aſia, as well "as in the civilized parts of Europe: The deli- "cate and unrivalled, as well as the coarſer and "more uſeful fabrics of cotton of that country "particularly ſuiting the inhabitants of the tem- "perate regions along the Mediterranean and "Euxine ſeas. To this trade (continues he) "the Perſian and Arabian Gulfs opened an eaſy "paſſage; the latter particularly, as the land "carriage between the Red Sea and the Nile, "and between the Red Sea and the Mediterra- "nean, took up only a few days. It is highly "probable, and *tradition in India* warrants the "belief of it, that there was from time imme- "morial an intercourſe between Egypt and Hin- "doſtan, at leaſt the maritime part of it; ſimi- "larity of cuſtoms in many inſtances, as related "of the ancient Egyptians by Herodotus, (and "which can hardly be referred to phyſical cauſes,) "exiſting in the two countries."—"It would "appear, that under the Ptolemies the Egypti- "ans extended their navigation to the extreme "point of the Indian Continent, and even ſailed "up the Ganges to Palibothra." See Memoir and Map of Hindoſtan, &c. 4to. by James Rennel, F. R. S.

The firſt, and perhaps the only good accounts of the practice of callico-printing in the Eaſt-Indies, were given in certain letters, written by Father

Father *Cœurdoux*, a miſſionary at Pondicherry, (publiſhed in the xxvith Volume of "Recueil "des Lettres Curieuſes & Edifiantes, &c.") with the Supplemental Remarks and Corrections of the celebrated Monſ. Poivre; and in a Manuſcript Account procured from thence by Monſ. du Fay, and communicated to the Royal Academy of Sciences at Paris, by the Abbé Mazeas.—By theſe accounts it appears, that the cotton cloths, when brought from the weavers, partly bleached, were worn next to the ſkin, by the dyer and all his family, during the ſpace of eight or ten days; after which they underwent ſeveral macerations in water with goats' dung, accompanied with frequent intermediate beatings, waſhings, and dryings, in the ſunſhine. Afterwards they were ſoaked for ſome time in a mixture of the mucilaginous aſtringent fruit of the yellow Myrobalans, Myrobalanus Citrina of Ray, (called "Cadoucaie,") well bruiſed, and of curdled buffaloes milk; and being thoroughly penetrated and impregnated therewith, they were taken out, and the liquor being well ſqueezed from them, were dried by expoſure to ſunſhine, and afterwards, by preſſure and friction, made ſmooth enough for being drawn upon by the pencil, with the different mordants. The firſt of theſe was an iron liquor (acetite of iron), ſimilar to that ſince employed by the callico-printers of Europe, excepting only that, inſtead of vinegar or alegar, the iron was diſſolved by a mixture of ſour palm wine, and of water in which rice had been boiled. This liquor was applied to the figures or ſpots intended to become black, and afterwards the aluminous mordant was applied, commonly by children, with the pencil, to the parts intended to be made red. To prepare this mordant, two ounces of allum were diſſolved in two quarts of water, taken from certain pits, wherein it was ſuppoſed to be better for this uſe than common water, though it was found on examination to have no particular taſte, and thirty ounces of it being evaporated, left only a reſiduum of eleven grains of ſea ſalt. To colour this ſolution, ſo that the ſtrokes of the pencil in applying it might be viſible, a little ſappan or ſampſan wood (Cœſalpinia Sappan, of Lin.) in powder was ſteeped in the ſolution, which being afterwards ſtrained, was thickened with gum, and applied as before mentioned; after which the cotton ſo penciled was expoſed to the hotteſt ſunſhine, in order that the parts to which the mordants had been applied might be dried as much as poſſible; and then the cottons were thoroughly ſoaked in large pits of water, to cleanſe them from the looſe ſuperfluous parts of the different mordants, as well as from the buffalo's milk, &c.; and this being done, they were dyed in water, with certain roots anſwering nearly in their effects to thoſe of madder. Of theſe there are ſeveral ſorts uſed for dying red in different parts of India, which will be more particularly mentioned hereafter; that pointed out by the accounts in queſtion, is deſcribed as a ſpecies of gallium, called on the coaſts of Coromandel and Malabar by the names of Chaia, Chayaver, and Raye de Chaye. The cottons penciled, &c. as before mentioned, and gradually made to boil in water with a ſuitable quantity of this root, were dyed *red*, where the ſolution of allum had been applied, and black in thoſe parts on which the iron liquor had been pencilled;

pencilled; and after being dyed, the cottons underwent three different washings with goats' dung, soap, &c. were then bleached by being exposed to the sun, and watered occasionally, to remove the stain on the parts intended to remain white.

It appears, that in this operation the buffalo's milk, and more especially the astringent juice of the Myrobalans, produced very important effects, by their attraction for the aluminous earth, by which they contributed greatly to decompose or separate it from the sulphuric acid, and consequently to fix it more firmly in the cotton; and being so fixed, it was enabled more strongly to attract and retain the colouring matter of the Chaia root whilst in the dying vessel, and thereby to produce a more permanent red in the different spots, figures, or designs where the allum liquor had been applied. A mixture of this and of the iron liquor, acting and applied in the ways before mentioned, produced also a durable purple in the same dying vessel, upon the parts impregnated therewith; and consequently one dying with the colouring matter of a single root, produced at the same time reds, purples, and blacks.

The East-Indian method of dying blue from indigo, (a substantive colour,) by covering over with wax the several parts intended to be reserved white, does not fall within our present inquiry. Neither is the yellow colour employed for callico-printing in that country deserving of much notice, it being composed only of a decoction of *cadoucaipou*, a species of galls, produced on the yellow Myrobalan tree, (which give a dull yellow,) and of a ſuitable portion of allum, which being thickened with gum, and penciled over blue figures or deſigns, produces a green, and on white parts or grounds, a yellow colour; neither of which is however ſufficiently durable. But in this compoſition we have an adjective colour directly combined, and topically applied with its baſis, inſtead of being applied ſeparately, as is moſt uſual.

Such compoſitions (which will be frequently under conſideration hereafter) aſſume the form of ſubſtantive colours, without being ſuch in reality; and as it may be uſeful to diſtinguiſh them by an appropriated term, I beg leave in future to call them *pro-ſubſtantive topical colours*, wherever an adjective colour, and its baſis or mordant, are thus mixed and applied together *topically*, either by the pencil or the block.

The art of callico-printing, ſince its introduction to Europe, has been diveſted of many tedious operations and manipulations, which indeed would have proved inſupportably expenſive here, on account of the higher price of labour, and of almoſt every thing neceſſary to human ſubſiſtence. But the greateſt European improvement in this art reſpects the aluminous mordant, and depends on the employment of ſugar of lead (acetite of lead), or the oxyd of that metal diſſolved by diſtilled vinegar, and cryſtallized; which within the memory of man has been gradually brought into uſe, without any theory or even ſuſpicion of its true effect, or of the way in which it proved ſo highly uſeful.

ful. This improved aluminous mordant is now generally made by diſſolving three pounds of alum in a gallon of hot water; then adding one pound, or in ſome particular caſes one pound and a half, of the acetite or ſugar of lead, ſtirring the mixture well during two or three days, and afterwards adding to it about two ounces of pot-aſh, and as many of clean powdered chalk (carbonate of lime). In this mixture, both the alum and the ſugar of lead are decompoſed by a double elective attraction, which produces two new compounds, according to Mr. Henry and Mr. Berthollet, becauſe the oxyd of lead having a ſtronger attraction for the ſulphuric acid than for that of the vinegar, combines with the former, and producing an inſoluble ſalt, ſubſides to the bottom of the liquor, whilſt the earth of alum, thus left in a very divided ſtate, unites to, and is diſſolved by the acetous acid, previouſly ſeparated from the lead, and remaining in the liquor, which thereby becomes a diluted acetite of alumine; the pot-aſh and chalk only ſerving to neutralize the exceſs of ſulphuric acid, which is always contained in alum, and which would in ſome degree hinder the alumine from being depoſited and fixed in the fibres of linen and cotton. But the decompoſition here deſcribed takes place only *in part*, becauſe one pound of ſugar of lead, or even one and a half, (the greateſt quantity any where propoſed,) is not ſufficient to decompoſe three pounds of alum. On the contrary, I have found that alum cannot be completely decompoſed, without two-thirds at leaſt of its weight of ſugar of lead; and where leſs has been uſed, I have always been able, by evaporation, to detect a quantity of it in the aluminous mordant. I ſhall have occaſion hereafter to revert to this ſubject, and ſhall therefore content myſelf at preſent with remarking, that the printers' aluminous mordant is not in fact a mere ſolution of the alumine, or earth of alum, by the acid of vinegar, as thoſe eminent chymiſts Mr. Henry and Mr. Berthollet ſuppoſe, but that even with the greateſt proportion of ſugar of lead ever employed by the calico-printers, it contains a conſiderable portion of alum in its original ſtate; I mean that in which the argillaceous earth or alumine is combined with ſulphuric acid. Notwithſtanding this circumſtance, however, I ſhall generally conſider this preparation as being in reality what it is not ſtrictly, an acetite of alumine, and ſhall commonly diſtinguiſh it either by that name, or by that of the printers' aluminous mordant.

The mixture or mordant in queſtion being thus made, and the clear liquor decanted from the ſediment, it is afterwards thickened with flour, if intended to be printed or applied by the block, and with the gum of the Mimoſa Nilotica (Gum Arabic), or of the Mimoſa Senegal (Gum of Senegal), if it be intended for penciling; and being applied in either of theſe ways to linens or cottons, it is afterwards very thoroughly dried in a room artificially heated, and then the pieces of linen or cotton, ſo printed or pencilled with the mordant in queſtion, are cleanſed as perfectly as poſſible, by ſoaking and working them in a ciſtern with warm water and cow-dung, and afterwards rincing them in clean water to diſſolve the gum or flour, and ſeparate the ſuperfluous or looſe parts of the mordant, which otherwiſe would in the dying veſſel combine with the colouring matter, and greatly ſtain the grounds, or parts intended to be preſerved white. This will indeed unavoidably happen in ſome degree, notwithſtanding the moſt perfect cleanſing. But as the colouring matter which theſe grounds or parts abſorb from the dying liquor will not, when the cloths have been thoroughly cleanſed, be retained or fixed by any baſis, they are ſpeedily whitened, by being boiled in water with bran, expoſed upon the graſs, and by other means well known.

By thus ſubſtituting the acetous for the ſulphuric acid in the aluminous mordant lately deſcribed, ſeveral conſiderable advantages are gained The acetite of alumine being much more ſoluble in water than common alum, the liquor will contain a much larger proportion of alumine than could be otherwiſe ſuſpended in it; and with this advantage moreover, that it will not be liable to form cryſtals in or upon the linens or cottons in drying, as would happen with a ſolution of common alum, the acetite of alumine being incapable of cryſtallization. I may add alſo, that the acid of vinegar being volatile, and having a much weaker attraction for its earthy baſis than the ſulphuric acid has, the former will be ſpeedily ſeparated and carried off, eſpecially by the heat of the ſtoves employed for drying the pieces printed with it, and will leave behind the alumine which it had held in a ſtate of ſolution, and which being no longer encumbered by any other attraction, will yield itſelf wholly to that which ſubſiſts between it and the fibres of linen or cotton, and will unite with them more copiouſly and firmly than it otherwiſe could do, and be thereby enabled more ſtrongly to attract and fix the colouring matters in the dying veſſel. This, however, will only prove true, ſo far as the ſulphat of alum has been really decompoſed by the acetite of lead, or ſo far as the alumine has been combined with the acetous inſtead of the ſulphuric acid.

As the practice of calico-printing has been but lately introduced into Europe, and as the acetated aluminous mordant does not appear to have been previouſly known in any other country, we might have expected that its diſcovery in this would have been deemed a matter ſo important, as to have conſtituted an era in the hiſtory of the art; and therefore I was not a little ſurpriſed in finding that no writer had mentioned, and that no calico-printer of whom I have inquired could inform me, at what time, or by whom this mordant was firſt employed, as the baſis of red and yellow colours in calico-printing. My wonder has, however, ceaſed on this ſubject, ſince I have inſpected a conſiderable number of recipes for making the ſeveral mixtures employed as mordants, ſoon after the buſineſs of calico-printing began to be carried on with ſome degree of ſucceſs here and in other parts of Europe. In one of theſe, which ſeems to have been the earlieſt, alum, ſal ammoniac, ſaltpetre, red orpiment, and kelp, were directed to be mixed with water. In another, which probably followed this, it was directed that theſe ingredients ſhould be diſſolved in vinegar. In a

ſucceeding

ſucceeding recipe, a little ſugar of lead was directed to be employed, but in a quantity too ſmall to be of any conſiderable uſe; I mean one ounce of it for every pound of alum. Afterwards the calico-printers, without any ſyſtem or reaſonable motive, appear in different inſtances to have added verdigriſe, arſenic, corroſive ſublimate, blue vitriol, *litharge*, and *white lead*. By ſtumbling upon the two laſt (which alone were of any uſe), it happened, where vinegar had been alſo employed, as it commonly was in ſome ſhape, that after a variety of decompoſitions and recompoſitions, ſome portion of acetite of alumine was formed, the good effects of which were experienced, though without any true knowledge of the ways and means by which they had been produced. By degrees, however, the printers ſeem to have increaſed the quantity of ſugar of lead, and ſeveral of them to have ſuſpected that many of the other ingredients uſually employed for making their mordants were uſeleſs. Some of them, therefore, began to omit one, and ſome another of theſe ingredients, until at length all the uſeleſs ones were laid aſide, though without the aid of any chymical reaſoning on the ſubject, and without any one ever ſuſpecting, as indeed few of them do at this day, that the lead which they continued to employ occaſioned any decompoſition of the alum, or that the mordant ſo produced did not really contain all the ingredients uſed in preparing it. Among the uſeleſs ingredients before mentioned, corroſive ſublimate ſeems to have been retained the longeſt, ſince Mr. Wilſon includes it in his recipe, which was publifhed fo lately as the year 1786. (See his Effay on Light and Colours, &c.)

It is not wonderful, therefore, that no particular perfon or period has been noted, or remembered as diftinguifhable for the firft invention of the acetated aluminous mordant; fince the fugar of lead, or other means of forming it, were at firft ufed by chance fo fparingly, as to have fcarcely produced any better effect than would have refulted from the mere folution of alum, and the alterations and improvements by which the mordant afterwards acquired its prefent form, I had almoft faid perfection, were made by fuch imperceptible gradations, and refulted fo much from the random additions and omiffions of different individuals, (no one of whom feems to have been guided by any thing approaching to a juft theory,) that neither the difcovery, nor any confiderable ftep towards it, can properly be referred to any one perfon or period.

Mr. Henry, juftly fenfible of the fuperior advantages of the acetated aluminous mordant in calico-printing, and conceiving it to have really been very anciently known and employed in thofe countries where the art was firft practifed, concludes from thence, that it muft have refulted from a very advanced ftate of chymical knowledge in thofe countries at fome very remote period, which was afterwards loft, whilft the improvements arifing from it in this refpect, continued to be practifed and handed down, through a long fucceffion of ages to the prefent

time.

time. " To have invented (ſays he) the pro-
" ceſs of printing, in the manner deſcribed by
" Pliny, the inhabitants of India muſt proba-
" bly have known how to prepare alum; they
" muſt have been acquainted with the manner
" of diſſolving lead in the vegetable acid; they
" muſt at leaſt have been acquainted with the
" component parts of theſe ſalts, and they muſt
" have had a knowledge of double elective at-
" tractions, &c." In truth, however, the inhabitants of India neither had, nor have they at preſent, any knowledge of the uſe of ſugar of lead, or of any other preparation of that metal which could produce ſimilar effects in calico-printing; a ſolution of common alum in water being their only aluminous mordant, and the previous application of the ſoluble parts of mirobalans to their calicoes, aided by a very hot ſunſhine, enabling them, without any thing like an acetite of alumine, to produce effects nearly equal to it. This fact I have learned not only from all the accounts publiſhed or tranſmitted to Europe reſpecting this point, but from the poſitive verbal informations of eye-witneſſes to the practice of calico-printing in that part of the world, and particularly of a gentleman of great veracity, as well as knowledge on this ſubject, who formerly carried on the buſineſs of calico-printing very extenſively in Bengal (principally for account of the Eaſt-India Company): and indeed ſugar of lead is ſo far from being uſed for this purpoſe there, that within a few weeks I have received a letter from Mr. John Adie, (ſucceſſor to the gentleman laſt mentioned,) dated, " Gondelpara, near Chandernagore, the 10th of February 1792," and mentioning, that

he had ſome little time before been obliged to pay twenty ſhillings the pound for ſugar of lead, in order to prepare a particular colour which I had formerly recommended; ſo far was this ingredient from being in uſe there for any ſuch purpoſe.

We may therefore ſafely conclude, that the formation of an acetite of alumine, and its application as a mordant in calico-printing, was not an oriental diſcovery; and that it did not reſult from any knowledge of double elective attractions, or any other extenſive chymical knowledge either in ancient or modern times; ſince thoſe who gradually ſtumbled upon and introduced the uſe of it, were totally ignorant of the decompoſitions and recompoſitions which took place in their mixtures, and always ſuppoſed, as all other calico-printers have till lately done, and as moſt of them now do, that the aluminous mordant really conſiſted of every thing uſed in producing it.

To illuſtrate more plainly the differences of colouring matter, as well as the action of an aluminous baſis upon them, let us examine its effects in a few particular inſtances: taking a bit of cotton upon which certain figures and deſigns had been printed, with the acetated aluminous mordant, and which, after being dried, had been cleanſed in the uſual way, I dyed it in water with ſaffron; the water readily extracted the yellow colour of the ſaffron, and the cotton ſoon imbibed ſo much of the colour as to become equally yellow in all its parts, without the leaſt appearance even of a difference

of

of ſhade where the alumine had been applied. The cotton ſo coloured being expoſed to air, ſoon became equally and uniformly white; the colouring matter of the ſaffron having no particular affinity to the alumine: to ſee, however, whether this laſt remained fixed in the fibres of the cotton, I dyed the ſame bit, which the ſaffron colour had thus abandoned, in water with a little Brazil wood, and the figures, where the alumine had been applied, became of a ſtrong, full, and moſt beautiful crimſon; the other parts, to which no baſis had been applied, being but ſlightly diſcoloured. The cotton ſo dyed being expoſed to the ſun and air two or three days, the ſpaces to which no mordant had been applied became perfectly white; the figures, impregnated with alumine, had loſt ſome of their fine crimſon colour, and this gradually diminiſhing, was all gone at the end of eight days. Here then we ſee, that the aluminous baſis had a certain affinity with the colouring matter of the Brazil wood, (which was not the caſe with that of ſaffron,) but not ſo much as to fix and retain it permanently. To ſee however that this was really the caſe, and that the defect aroſe from the want of a ſufficient affinity between the colouring matter and the alumine, and not between this laſt and the cotton, I took the ſame bit which had been already twice dyed, and dyed it a third time in water with madder, whereby the whole bit became coloured, but the figures impregnated with alumine much more deeply than the other parts; a proof that the alumine ſtill remained fixed, notwithſtanding the eſcape of the Brazil wood crimſon, and that it had again entered

entered into a triple combination with the madder colour, and the fibres of the cotton. The bit ſo dyed, being well boiled in water with bran and expoſed to ſunſhine and air, in a few days became white in the parts where no mordant had been applied to fix and retain the colour, whilſt the figures formed by the application of alumine retained all their body and brightneſs; the colouring matter of the madder, in this triple combination, not being liable to deſtruction or ſeparation by the ſame means which deſtroyed or ſeparated it where no ſuch bond of union or means of preſervation exiſted.

It has been already noticed, that in oriental calico-printing the ſolution of alum is coloured red with ſampſan or ſappan wood; and I might have added, that in dying with roots analogous to thoſe of madder, the red colour of the wood is diſlodged from the pores of cotton by the ſuperior attraction of the root colour, which takes its place. Neither the Eaſt Indians, however, nor the writers who have given accounts of their operations, ſeem to have been appriſed of this fact; but concluded that the red wood colour was fixed and made durable by the application of that of the roots. To aſcertain the truth on this point, I dyed a bit of cotton impregnated with acetate of alumine like that laſt mentioned, with Brazil wood, and the figures impregnated with the mordant became as before of a fine crimſon colour. I then rinced the dyed cotton, and putting it into another veſſel with clean water, added gradually ſo much decoction of madder as was ſufficient for that weight of cotton,

cotton, and dying it in the usual way, I found that I had a madder red instead of the fine Brazil wood crimson. The colouring matter of madder having decomposed and dislodged the Brazil wood colour, with which the water was visibly tinged, and which being divided into several parts, and tried by different chymical agents, underwent all the changes which are usual to the colouring matter of Brazil wood, and not those which happen in the like circumstances to the colour of madder. The bit of cotton, to which the madder colour had applied itself by dislodging that of the Brazil, being also tried in various ways, manifested the durability and other appearances usual to madder colours.

If cottons printed with the acetated aluminous liquor, as before-mentioned, be dyed with Weld or Quercitron bark instead of madder, this basis will attract their colouring particles in the same manner, and produce permanent yellows upon the figures where the alumine was previously fixed; the other parts being but slightly tinged, and being afterwards easily bleached or whitened, because there is no mordant to hinder the separation or destruction of the colouring matter of these dying drugs. The dying of yellows, however, in this way, is an European invention; the people of India having only given them, as already mentioned, by a *pro-substantive* mixture of the decoction of the galls of mirobalans with alum. And indeed this practice was followed here for some time after the introduction of the art into Europe, excepting that instead of the galls of the mirobalan tree,

a de-a decoction of French berries (Rhamnus infectorius, Lin.) was employed; by which, indeed, a very full bright yellow was at firſt communicated, but of ſo *fugitive a nature*, that the uſe of theſe berries, which in ſome degree ſtill ſubſiſts, ought to be prohibited; it being impoſſible, by any means yet known, to obtain from them a colour fit for any other purpoſe than that of deception. If inſtead of the aluminous baſis, cottons or linens be impregnated with iron liquor (acetite of iron) of different degrees of ſtrength, and dyed with madder, they will receive permanent dark browns of different ſhades, and even a full black: and if inſtead of iron liquor alone, it be mixed in different proportions with the acetite of alumine, the mixture will produce with madder all the ſhades of flea-colour, purple, violet, &c.

But when, inſtead of madder, cottons or linens are printed with iron liquor, and dyed with weld (Reſeda Luteolu, Lin.) or Quercitron bark, (Quercus nigra, Lin.) they receive a variety of olive-brown, drab, and dove colours; and if inſtead of iron liquor alone, a mixture of it, with acetite of alumine, be uſed as a mordant, they will take various ſhades of olive, olive-green, &c. And, indeed, by the help of theſe two mordants only, (from iron and alumine,) uſed ſeparately, as well as mixed in various proportions, and afterwards combined with the colouring matters of madder and of weld, or (inſtead of the latter) of Quercitron bark, aided by the blue from indigo, nearly all the poſſible varieties and ſhades of colour are now given in the way of calico-printing.

Hitherto

Hitherto the art of calico-printing has been confined almoſt ſolely to linens and cottons, which are ſuited to it, by being ſuſceptible of a permanent union with colouring matters, and eſpecially with their baſes, by only the common warmth of the atmoſphere: and as this is alſo the caſe of ſilk, there can be no doubt but this laſt might be made the ſubject of new and beauful embelliſhments in that way, which, if properly executed, would undoubtedly become a ſource of gratification to the public, and of profit to individuals.

Very lately indeed a ſpecies of topical dying or ſtaining, very much reſembling ſome parts of calico-printing, has been ingeniouſly applied to woollen ſtuffs, and particularly thoſe called kerſeymeres, for waiſtcoat patterns, &c. What I mentioned in a former chapter, of the neceſſity of a conſiderable degree of heat, to enable the fibres of wool to receive and combine with colouring matters, will afford ſome idea of the difficulty of applying and fixing different colours in the form of ſpots or figures upon woollen ſtuffs in this way by dying; the particular mode and means by which this difficulty is overcome, and the ſeveral colours fixed in the fibres of wool, are ſtill kept ſecret as much as poſſible. How proper colours for this purpoſe may be provided, either from ſubſtantive colouring matters, or from the adjective ones, made into the form of a ſtrong decoction, and mixed with the proper mordants, (as in the inſtance which I lately noticed of a pro-ſubſtantive yellow,) will be eaſily underſtood by thoſe who may attend to what has been, or will be explained in the courſe of this work; and ſuch colours being ſo prepared, and printed upon kerſeymere, &c. in the uſual ways, may be, as I have found on trial, and as I am informed they are, made to penetrate and unite with the wool, by placing the ſtuff ſo printed in the ſteam of boiling water for a ſufficient length of time, firſt wrapping it up in thick paper, doubled or trebled, ſo as to exclude the moiſture, ſo far at leaſt that it may not occaſion the colours to run beyond their proper limits.

After this ſummary account of the origin, progreſs, and nature of calico-printing, intended to illuſtrate more diſtinctly the effects of the principal baſes or mordants, it will be proper here to take a general view of the facts which reſpect the application of theſe baſes, for fixing and modifying different adjective colours, not by topical, but by general dying, as well upon wool and ſilk, as on linen and cotton.

The two laſt of theſe are made fit for the application of a baſis, by being boiled for the ſpace of two or three hours in a ſolution or ley of pot-aſh of ſuitable ſtrength; then ſpread for ſome time on the bleaching ground; afterwards ſoaked in water, made ſour by the addition of one-fiftieth or ſixtieth of its weight of ſulphuric acid or oil of vitriol, and finally rinced thoroughly in clean water, and dried. When thus prepared, if the aluminous baſis is intended to be applied to them, perhaps there is no form in which it could be more effectual than that of the acetated aluminous mordant, though motives of œconomy have always induced the mere dyers of

linen

linen and cotton to employ cheaper preparations of alum. The sulphate of alumine, or common alum, will indeed yield a considerable part of its earthy basis to linen and cotton, when dissolved by water and applied to them; but it does this more readily when deprived of its excess of acid by pot-ash or calcareous earth; and it is in this way commonly employed as a mordant for linens and cottons. About four ounces of alum, with water sufficient to dissolve it, and half an ounce or somewhat less of pot-ash, being generally allowed for each pound of linen or cotton intended to be dyed, which is to be macerated, &c. in this liquor until thoroughly and equally penetrated by it, and afterwards well rinced to separate the superfluous or loosely adhering alum, &c. Cotton treated in this way commonly gains about two and a half per cent. additional weight, by the earth of alum which combines with it. But where no white grounds are to be reserved, there are ways of rendering the aluminous basis more effectual, and particularly for madder colours upon linens and cottons, by impregnating them at the same time with oleaginous, resinous, glutinous, and alkaline substances, which occasion an increased affinity or attraction between the fibres of the linen and cotton, as well as between these and the colouring matters, thereby forming perhaps a kind of cement, which renders them more fixed, and less liable to be acted upon and injured by those causes which generally destroy or weaken colours.—These auxiliary means will hereafter be noticed in their proper places.

Silk is impregnated with the aluminous basis by macerating or soaking it only during the space of ten or twelve hours in a saturated cold solution of alum, afterwards rincing it, &c.

To impregnate wool with the aluminous basis, it is commonly boiled in water with about one-sixth or one-eighth of alum, and about half as much tartar. The heat is gradually raised to the boiling point, and the liquor kept boiling for about an hour; then taken out, drained, and left until the next day, when it is well rinced. Wool, from its animal nature, has a much stronger attraction for alumine than either silk, linen, or cotton, but will not decompose a solution of alum without the aid of a considerable degree of heat. Tartar, as Mr. Berthollet observes, seems principally useful in this way, by moderating the strong action of alum upon the fibres of the wool, and preventing too great a deposition of the aluminous earth in their pores, which would render the fibres apparently coarser. Perhaps, however, a more sparing use of alum might in some degree obviate the necessity of using tartar for this purpose; and some dyers have lately omitted the use of it in many cases where it was formerly always employed, particularly in the boiling preparation for weld yellows. Tartar has, however, other considerable effects in modifying and varying the shades of colours, as will be seen hereafter.

For the dying of wool and silk, the basis of iron is usually employed subsequently to the colouring matter which it is intended to fix and modify,

modify, or interchangeably with it; and in these ways copperas (sulphate of iron) is most frequently used. Alumine and iron in some form or other were very anciently employed as mordants in dying; and indeed they seem for many ages to have been the only substances used as such, which is at present nearly the case in calico printing. Mr. Hauffman, in a letter very lately written to Mr. Berthollet, (see Ann. de Chymie, tom. vii.) maintains, "that of all acid, "alkaline, earthy, and metallic substances, "there is, strictly speaking, none, excepting "the oxyd of iron and alumine, which pos-"sesses the property of attracting the colouring "particles of drugs proper for dying, such as "madder, weld, logwood, &c. which sepa-"rately or combined, and differently modifi-"ed, are capable of producing with these sub-"stances an infinite variety of colours, and "shades of colour, more or less durable." Here, however, Mr. Hauffman is misled, by confiding in his own experience as a calico-printer only; for in dying, it is notorious that the oxyds or solutions of several of the metals besides iron, and particularly those of tin, copper, and zinc, are used to fix colours, in consequence of the attractions which they exercise upon the colouring particles of different dying drugs; and it will be hereafter proved, by my own particular experiments, that there is none of the metals or semi-metals, nor any even of the different earths, which does not in some state and degree at least possess a power, not only of modifying colours, but of attracting and fixing colouring particles more or less ſtrongly in the way of dying; though it muſt be confeſſed, that of the ſeveral earths, none is in this reſpect ſo powerful and ſo uſeful as the alumine; indeed this and the oxyd of tin ſeem to be the only baſes ſuited by their perfect whiteneſs to reflect the rays of light, ſo as to exhibit the natural colours of the different adjective dyes with full luſtre; every other baſis hitherto known having been found in moſt, if not in all caſes, to darken or ſadden, perhaps I might ſay degrade, the natural colours of theſe dyes, at leaſt in ſome degree. Probably zinc does this leſs than any other metallic baſis, excepting tin, which indeed, with a very few exceptions, reflects the rays of light more copiouſly, and exhibits colours more brilliantly than alumine, becauſe its oxyd unites with colouring matters as a baſis, in a much larger proportion than the alumine will do. Perhaps alſo the particles of this oxyd are more perfectly white than thoſe of alumine. In moſt caſes, however, the attraction which a metallic baſis exerts upon an adjective colour in dying, is not ſimply the reſult of its own affinity with the particles of that colour, but of its own affinity combined with the affinity of the ſtuff imbibing the dye. Thus in the dying of ſcarlet, it is every day ſeen that pieces of woollen cloth or ſtuff, having at each edge a narrow longitudinal ſtripe, formed by an intermixture of cotton yarn, after being impregnated in the uſual way with the mordant or oxyd of tin, will attract and imbibe the colouring particles of cochineal, ſo as to exhauſt the dying liquor, and ſometimes leave it perfectly colourleſs, and become ſcarlet in every part,

excepting

excepting the ſtripes formed of cotton-yarn, which always come out of the dying liquor without the ſmalleſt tinge or change of colour, though both the mordant and the particles of cochineal are applied to the latter equally with the other parts of the cloth. Here then either the oxyd will not combine with the fibres of cotton, whilſt it is ſubject to a ſtronger attraction from the woollen part of the cloth; or if it does combine with the fibres of cotton, their joint attractive power is ſo much weaker than that which the oxyd of tin and the wool united exert upon the cochineal, that they are unable to draw and fix any part of the colouring matter to or in the cotton, ſo long as this colouring matter is liable to the prevailing attraction of the wool and oxyd of tin united; and that this latter is really the caſe, will appear by experiments to be mentioned hereafter.

Mr. Berthollet, as will be remembered, conſiders not only the decays of colours, but their production in many caſes as the reſult of ſome degree of combuſtion; and upon this principle he maintains, " that the colour which the com-
" pounds of metallic oxyds and of colouring
" particles aſſume, are the product of the co-
" lour peculiar to the colouring particles, and
" alſo of that which is peculiar to the metallic
" oxyd; but, adds he, the colouring particles
" and metallic oxyds muſt be conſidered as in
" that ſtate to which they have been reduced
" by the diminution of oxygene in the oxyd,
" and of hydrogene in the colouring particles."
" Hence (continues Mr. B.) metallic oxyds, to
" which the oxygene is but ſlightly attached, are

" not fit to ſerve as connecting media for the " colouring particles, becauſe they produce in " the latter too great a degree of combuſtion; " ſuch are the oxyds of ſilver, gold, and mer- " cury." " That oxyds which undergo con- " ſiderable changes of colour, by giving off " more or leſs of their oxygene, are alſo bad " intermedia, eſpecially for light ſhades, be- " cauſe they produce changeable colours; ſuch " are the oxyds of copper, lead, and biſmuth." " That the oxyds which ſtrongly retain their " oxygene, and ſuffer but little change of co- " lour by loſing a part of it, are beſt fitted to " anſwer this purpoſe; ſuch, ſays he, is parti- " cularly the oxyd of tin, which quits its men- " ſtruum eaſily, has a ſtrong attraction for co- " louring particles, and affords them a baſis " very bright and very proper to reflect their " colours with luſtre, unaltered by the admix- " ture of any other ſhade of colour. The " oxyd of zinc poſſeſſes ſome of theſe proper- " ties."

" We muſt then diſtinguiſh, (adds he,) in the " action of mordants, the combinations that may " take place by their means between the colour- " ing particles, the ſtuff, and the intermediate " baſis; the proportions of this latter, and of the " colouring ſubſtance; the modifications of co- " lour which may ariſe from the mixture of the " colour of the colouring particles, and of that " of the baſis to which they are united; and " finally, the changes which the colouring par- " ticles may ſuffer from the *combuſtion* produced " by the intermediate baſis."

I have

I have already noticed ſome facts which induced me to diſtruſt that part of Mr. Berthollet's theory, which ſuppoſes the decays of colours to depend upon combuſtion, at leaſt in many caſes; and there are ſome which appear equally ſtrong againſt that part of it which aſcribes their production to a like effect. Upon this ſubject, however, I will at preſent only obſerve, that in many caſes both alumine and metallic oxyds, when diſſolved by pot-aſh, ſoda, and ammoniac, produce, with particular dying drugs, colours exactly ſimilar to thoſe, which the ſame baſes, diſſolved by nitric acid, produce with the ſame drugs; though in the former caſe it is difficult to conceive how the metallic oxyd, and eſpecially the alumine, ſhould furniſh oxygene to produce the ſuppoſed combuſtion; whilſt in the latter theſe different baſes, by having been combined with nitric acid, certainly might furniſh the means of combuſtion; and ought therefore, upon Mr. Berthollet's ſuppoſition, to produce darker colours than thoſe which reſult from the ſame baſes, united with volatile alkali, ſoda, and pot-aſh.

It ſeems therefore moſt probable, that when the oxyds of metals alter the natural colours of dying drugs, the new colours thus produced are the ſpecific reſults of the particular combinations between ſuch oxyds and the drugs united to them, independently of any effect ſtrictly deſerving the name of combuſtion.

Having thus generally explained and illuſtrated the properties and uſes of mordants or baſes, in fixing and modifying adjective colours by dying, I ſhall proceed to a particular inquiry concerning their effects upon each of the more important dying drugs of this claſs, beginning with thoſe which belong to the animal kingdom, and proceeding to the vegetable.

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## CHAP. VIII.

### *Of Pruſſian Blue.*

" Preſque tous les arts doivent leur naiſſance au hazard; " ils ne ſont en general, ni le fruit des recherches " ni le reſultat des combinaiſons; mais tous ont un " rapport plus on moins marqué avec la Chymie; " et elle peut en eclairer les principes, en reformer " les abus, ſimplifier les moyens & hater leur pro- " gres."

CHAPTAL, *Elemens de Chymie.*

MANY reaſons induce me to conſider the tingent matter of Pruſſian blue as an *animal adjective colour* *, which becomes blue when united to iron and to ſome other metallic baſes; but is at the ſame time capable of producing other very different colours, when combined with certain other metallic oxides or baſes.

The firſt diſcovery of Pruſſian blue, or pruſſiate of iron, as related by Stahl, was

* I know that ſome vegetable, and perhaps ſome foſſil matters, poſſeſs a power of producing blue precipitates with iron; but however theſe may reſemble in appearance the Pruſſian blue, their properties are not identically the ſame.

like many other interefting difcoveries, purely the effect of accident. About the year 1710, *Diesbach*, a chymift at Berlin, wifhing to precipitate the colouring matter of cochineal from a folution or decoction, in which it was combined with a portion of green vitriol, or fulphate of iron, borrowed for that purpofe from his neighbour Dippel, an alkali, upon and from which the latter had feveral times diftilled an animal oil, and which had thereby become impregnated with the animal colouring part of Pruffian blue: confequently this alkali, when mixed with the decoction of cochineal, or rather with the iron contained therein, immediately and moft unexpectedly produced a very beautiful blue colour. The experiment being repeated, and always with the fame effect, Diesbach availed himfelf of the difcovery; and this new colour was made known and fold under the name of Pruffian blue. The means of producing it were however kept fecret until the year 1724, when Dr. Woodward publifhed an account of the procefs in the Philofophical Tranfactions. The cheapeft way of preparing this animal blue is, by burning dried blood, horns, hooves, hides, tendons, and other animal fubftances, fo as to reduce them to coal; which is afterwards to be calcined with three times its weight of pot-afh in an iron veffel. After about twelve hours of calcination, the mixture generally appears like a foft pafte, and then it is to be thrown into tubs nearly filled with water, and being there diffolved, the folution is filtered, and mixed with another, compofed of three parts of alum, and one of copperas, in a fufficient quantity of water. By this mixture, the animal colouring matter becomes united to the oxide of iron, and fubfides with it to the bottom of the liquor of a blue colour; and this is to be feparated by the filter.

The oxide of iron, as Mr. Berthollet obferves, may combine in different proportions with the colouring part of Pruffian blue. Where it is in excefs, the compound will be yellow; but when the oxide is in a fmaller proportion, the colour will be blue. All acids, and particularly the muriatic, are capable of diffolving the excefs of iron, fo as to bring the compound to the proper ftate and appearance of Pruffian blue. But farther than this, acids have no power of decompofing or diffolving any part of it. The animal colouring part of Pruffian blue (feparated from the oxyd of iron), is called the Pruffian acid, though I think improperly, becaufe there is apparently no more reafon for calling it an acid, than there would be in giving that name to the colouring particles of cochineal, and moft other dying drugs. It is indeed commonly united to a portion of phofphoric acid, not becaufe this laft is a neceffary conftituent part of it, but becaufe it naturally exifts in the different animal fubftances, from which the Pruffian colour is obtained. Scheele has defcribed a procefs for obtaining the Pruffian acid, which I beg leave hereafter to call the Pruffian Colouring Matter, in its pureft ftate; and in this ftate, though capable of recompofing Pruffian blue, with the oxide of iron, it

contains

contains no phoſphoric acid, and therefore this acid cannot be a neceſſary component part of the Pruſſian colouring matter.

Pruſſian blue, though not ſoluble by acids, diſſolves readily both by pot-aſh and ſoda in their cauſtic, and alſo their mild ſtates; and the ſolution is then colourleſs, or at moſt only of a very pale ſtraw colour. This ſolution, when made with pot-aſh, is denominated pruſſiate of pot-aſh, and when with mineral alkali, pruſſiate of ſoda. It contains a portion of iron in a ſtate of ſolution, and therefore the blue colour may be reſtored by any of the acids, in ſome degree at leaſt.

Ammoniac or volatile alkali, digeſted in a moderate degree of heat upon the Pruſſian blue, diſſolves and unites with the colouring matter, forming with it a pruſſiate of ammoniac.

Lime-water alſo, moderately warm, diſſolves the Pruſſian colouring matter, (as M. Fourcroy firſt obſerved,) and holds it in ſolution without the oxide of iron. This ſolution, or pruſſiate of lime, is of a pale yellow colour.

I have ſtated theſe facts reſpecting the Pruſſian blue, becauſe they are particularly connected with its uſe in dying. Thoſe who wiſh for farther information reſpecting it, may refer to an intereſting "Memoire" on this ſubject, by Mr. Berthollet, of which an extract is contained in the firſt volume of the Annales de Chymie. He concludes, that the Pruſſian colouring matter conſiſts of azote, hydrogene, and carbone, combined

combined in certain proportions, not yet accurately aſcertained; and that animal ſubſtances aſſiſt in forming it, by ſupplying a portion of azote which they contain.

The uncommon beauty and luſtre of the Pruſſian blue, have occaſioned many endeavours to apply and fix it equally and permanently as a dye. The late Mr. Macquer propoſed two methods of doing this, but neither proved ſucceſsful. In the firſt he ſoaked the ſtuffs in a ſolution of alum and copperas, and then in a diluted pruſſiate of pot-aſh (Pruſſian blue diſſolved by pot-aſh); and laſtly, in water a little ſoured by ſulphuric acid, in order to diſſolve and remove any ſuperfluous oxide of iron. By doing this repeatedly, he produced a very beautiful blue colour, but it took unequally, and the texture of the ſilken and woollen ſtuffs was rendered very harſh.

In Mr. Macquer's ſecond proceſs the ſtuffs to be dyed were boiled in a ſolution of alum and tartar, and afterwards in water containing Pruſſian blue, which had been finely powdered. In this, however, the colouring particles were only ſuſpended, without being diſſolved, and therefore, though they were applied to the fibres of the ſtuffs, it was without any chymical union, and ſo ſparingly as only to produce very faint ſhades of colour.

The Abbé Menon recommended a different proceſs for dying linens and cottons with the Pruſſian blue. They were firſt dyed black in the uſual way, with a ferruginous baſis; and then

then ſoaked a few minutes in a diluted ſolution of Pruſſian blue, made by pot-aſh; after which they were boiled in water with alum, and took thereby a deep blue. In this caſe the Pruſſian colouring matter ſeemed to exert a ſtrong attraction upon the oxyd of iron contained in the black dye, and thereby to decompoſe and ſeparate the vegetable colouring matter (of galls, &c.) and in its ſtead to combine with the ferruginous baſis. Mr. Berthollet, however, obſerves, that this effect does not take place unleſs the Pruſſian blue has been diſſolved with an exceſs of pot-aſh, and I am perſuaded it is chiefly owing to the boiling with alum which diſcharges the colouring matter of the galls, &c. leaving only that of the Pruſſian blue united to the ferruginous baſis.

Some years ſince M. Roland de la Platriere publiſhed among the "Arts et Metiers" of the Royal Academy of Sciences at Paris, an account of another method practiſed at Rouen for dying with the Pruſſian blue, in many reſpects ſimilar to Mr. Macquer's ſecond proceſs, but with this difference, that the Pruſſian blue in fine powder was ſuſpended, not diſſolved, by a diluted muriatic acid, inſtead of pure water; a change which ſeems to have been attended with ſome advantage, though it was with difficulty, and not without many precautions and tedious operations, that an equal colour of ſufficient body could be obtained; and then, though highly beautiful, it was not in a ſtate of chymical combination with the fibres of the cotton velvets, for which it was principally uſed, and therefore was liable to be eaſily abraded by wearing

wearing and friction, especially in those places where it had been folded. Air, however, did not weaken the colour in any degree, nor was it injured by acids.

A little time before this, M. le Pileur d'Apligny announced to the world that he had discovered the means of dying a blue, as far exceeding all other blues in beauty and lustre, as the cochineal scarlet exceeds the common reds. He, however, kept his process secret, until the offer of a premium induced him to make it public. He began it by impregnating the stuffs to be dyed with an iron basis, which he prepared by deflagrating equal parts of old iron and saltpetre in a crucible, afterwards washing the residuum and dissolving it in vinegar and bran-water. This being sufficiently diluted, was applied as a mordant in the usual ways to the stuffs, which were afterwards well rinced, and dyed in a preparation of Prussian blue, made by dissolving two pounds thereof (in the moist state in which it is first precipitated) by half a pound of pot-ash, in boiling water, and afterwards adding three ounces of common oil of vitriol, or an equivalent portion of nitric acid, so as to neutralize the alkali, without precipitating the colour. A sufficient quantity of this put into a dying vessel, with hot water, and the stuffs, previously impregnated with the iron mordant, being dyed therein, they became at first green, and afterwards of a beautiful blue colour; which was, however, still liable to take unequally, and therefore M. d'Apligny's process, as far as I can learn, has never been carried into any considerable use.

In

In the thirteenth Volume of the "Annales de Chymie," (for April laſt,) Mr. Berthollet gives an account of certain ideas which had occurred to him reſpecting the defects of all the means uſed for dying with Pruſſian blue, and of ſome experiments made at his deſire by Mr. Vidmer, of the celebrated calico-printing eſtabliſhment at Jouy, for correcting theſe defects. It was found by theſe experiments, that pieces of cotton, impregnated with the acetite of alumine or iron liquor, notwithſtanding all poſſible endeavours to apply it equally, took up the colour of Pruſſian blue (firſt diſſolved by pot-aſh, and then mixed with either ſulphuric or muriatic acid) ſo very unequally, as to leave no hope of ſucceſs in this way. Mr. Berthollet accounts for this inequality of colour, by ſuppoſing that one part of iron is ſufficient for ſix of the Pruſſian colour; and that therefore the ſlighteſt difference in the diſtribution of the particles of that metal in the mordant, becomes very ſenſible when the Pruſſian colouring matter is afterwards ſuperadded thereto.

Mr. Vidmer was particularly ſtruck with the greens which were produced with the Pruſſian blue, upon patterns previouſly dyed olive in the uſual way by the iron liquor and weld, which greens greatly ſurpaſſed in beauty all thoſe given by any other means.

Mr. Berthollet, by experiments which were afterwards made ſeparately from Mr. Vidmer, diſcovered that the ſolution of Pruſſian blue by lime water (pruſſiate of lime) ſucceeded as well

well as that by pot-aſh, and that it required leſs care reſpecting the proportions: but he thinks the alcaline ſolution will have the advantage of being afforded cheaper, becauſe when animal matters have been calcined with pot-aſh, nothing more will be neceſſary than to ſaturate the exceſs of alkali, by adding to it a little Pruſſian blue.

Mr. Berthollet's method was to dilute the pruſſiate of lime with three or four times as much water, or to dilute with a large quantity of water, a ſmall one of the pruſſiate of pot-aſh, and then to mix with it a little ſulphuric acid, and keeping the liquor at a heat of between twenty and thirty degrees of Reaumur's thermometer, to immerſe the cotton, linen, or ſilk therein, (having firſt ſoaked it in warm water,) and turn it over a winch, &c. as uſual, in order that the colour might be equally applied. The dye was found to take ſufficiently in a few minutes, and then the ſtuffs were taken out and waſhed in cold water. He found the ſulphuric acid preferable to the muriatic.

Cotton and ſilk previouſly dyed gray or brown, with galls or other nigreſcent vegetable colouring matters, applied to a ferruginous baſis, acquired by the proceſs juſt mentioned a blue colour, proportioned to the depth of the former brown or gray; and thoſe which had been previouſly dyed olive, by the application of weld, or other adjective vegetable yellows, took alſo a beautiful green, proportionate to ſuch olive colour. He ſays nothing of the ef-

fects

fects of this method of dying on wool, having made ſcarce any trials therewith.

Cotton and ſilk dyed black by the ordinary means, were found, by ſuperadding a blue in Mr. Berthollet's method, to become more perfectly black, as well where the original colour had faded, as where it had been but imperfectly produced at firſt. He cautions againſt uſing too much acid, as well as againſt making the dying liquor too hot, and keeping the ſtuffs too long therein, eſpecially the ſilk, which would thereby loſe ſome of its luſtre and ſoftneſs.

One great defect, however, attending this method of dying, eſpecially upon cotton, is, that the ſtuffs, to which the Pruſſian blue has been applied, will not bear waſhing, becauſe, though the colour reſiſts air extremely well, the alkali contained in ſoap readily diſſolves and ſeparates the Pruſſian colouring matter. As a remedy for this defect, Mr. Berthollet recommends waſhing the cottons, dyed by his proceſs, with bran and water, inſtead of ſoap, which, he ſays, will likewiſe have the advantage of preſerving the other colours of printed cottons; or rather of not injuring them, as waſhing with ſoap generally does in ſome degree. Among the effects mentioned by Mr. Berthollet, that which I thought the moſt ſurpriſing was, the change of what he (improperly) calls an *olive* colour, *produced by weld and iron liquor*, to a very beautiful green, by the application of Pruſſian blue in the way before deſcribed. The *green* in this inſtance could not be produced without a mixture of *yellow* with the blue; and weld, the only colouring

colouring ſubſtance from which it could in this caſe be obtained, never would afford any ſuch colour without the aluminous or ſome other baſis very different from iron. I determined therefore, as ſoon as poſſible, to aſcertain the truth reſpecting this point; and for this purpoſe I took a large piece of cotton, which had been printed in parallel longitudinal ſtripes, firſt with a mixture of iron liquor and galls, next with iron liquor only; then with a mixture of iron liquor and the aluminous mordant (acetite of alumine); and laſtly with the aluminous mordant only; then followed a white ſtripe to which nothing had been applied, and theſe were repeated ſo as to cover the piece. This I dyed in the uſual way with a decoction of Quercitron bark, and thereby the firſt ſtripe became black, the ſecond of a dark drab colour, the third of an olive, and the fourth yellow. I then took a ſolution of pot-aſh, fully ſaturated with the Pruſſian colouring matter, and poured ſome of it into a large veſſel nearly filled with moderately warm water, to which I added a large proportion of oil of vitriol (ſulphuric acid): this, from its weight, ſunk to the bottom. I took care, however, by ſtirring, to mix it thoroughly with the liquor; which became uniformly blue, and had a ſour taſte. I then tore off a ſtrip of the dyed cotton of the whole breadth of the piece, and immerſed it for a ſingle minute only in the liquor; when, on taking it out, I found that every particle of the colouring matter of the galls and Quercitron bark had been diſcharged, and replaced by the Pruſſian colouring matter upon the ſtripes where an iron baſis had been at firſt applied, nearly according to the quantum of that

baſis.

basis. The first stripe, therefore, instead of being black, was of a very full, deep, strong blue colour; the second was sufficiently full, though very sensibly weaker; and the third was still weaker; the fourth, to which the aluminous basis only had been applied, was of a very pale bluish colour, almost as slight as the fifth, which had not been impregnated with any basis or mordant. To diminish the excess of sulphuric acid in the liquor, as well as to replenish it with colouring matter, I added thereto a farther portion of prussiate of pot-ash, which being properly mixed, I immersed another strip torn from the same piece of cotton, and taking it out also, after a single minute, I found that in this instance the excess of sulphuric acid had not been great enough to discharge the colouring matter of the galls, though it had totally discharged that of the Quercitron bark. I had, therefore, instead of a very dark blue on the first stripe, a very full black, greatly superior to what it had been originally, the black from galls and iron having become much more intense by an additional body of blue colour. All the other stripes were very similar to those of the preceding trial. I then perfectly neutralized the excess of acid in the dying liquor, by adding to it a sufficient quantity of prussiate of pot-ash; and a third strip of the same cotton being put into it for the same space of time, I found that none of the colouring matter of the Quercitron bark was discharged in those parts where it had been united to the aluminous basis, though it appeared to have been decomposed and separated from the ferruginous, and its place supplied by the colouring matter of the Prussian blue. I had therefore on the ſecond ſtripe a blue colour, inſtead of the drab which the Quercitron bark had produced with the iron liquor; and on the third ſtripe, inſtead of an olive, I had a very beautiful green, compoſed partly of the yellow from the Quercitron bark and the aluminous baſis, and partly of the blue which the Pruſſian colouring matter had produced on the ſame ſtripe, by uniting with the ferruginous particles of the iron liquor, originally mixed with the acetite of alumine, and applied as a mordant upon that ſtripe. The yellow upon the fourth ſtripe remained in full perfection; and the fifth ſtripe was perfectly white, having been quite freed from a ſlight diſcolouration which the Quercitron bark had produced on it in the dying veſſel. By this, and many ſimilar experiments, made ſome of them with weld inſtead of Quercitron bark, I clearly perceived that Mr. Berthollet muſt have been miſtaken, when he ſuppoſed that the olives which were changed into beautiful greens in the manner before mentioned, had been given by the weld and iron liquor *only*, becauſe no ſuch effect can be produced either from that or any other adjective vegetable colouring matter, without the aid of alumine, or of oxide of tin, to produce a yellow, whilſt the ferruginous baſis, by attracting the Pruſſian colour, produces a blue, the other component part of the green. I aſcertained this fact more completely by extending my experiments to woollen cloth, of which Mr. Berthollet ſays nothing in this reſpect. I began by dying pieces of white broad cloth, ſome with weld and copperas, others with Quercitron bark and copperas, which in both caſes produced nearly the ſame

ſame drab colours; and the pieces being ſo dyed, I immerſed them in different portions of diluted pruſſiate of pot-aſh neutralized, with ſulphuric acid, a little more than blood-warm, in which they all, after ten or fifteen minutes, became blue, the Pruſſian colouring matter having decompoſed and ſeparated that of the weld and Quercitron bark, which by ſuitable experiments I afterwards found to be contained in the ſeveral liquors where the Pruſſian colouring matter had before been ſuſpended. If inſtead of dying the cloth with weld or Quercitron bark and copperas only, I uſed alum along with copperas, an olive was produced; and this being ſoaked as before mentioned in warm diluted pruſſiate of pot-aſh, neutralized with ſulphuric acid, produced a green; the alum and Quercitron bark or weld furniſhing a ſufficient quantity of yellow for that purpoſe. In all theſe and many other experiments I found, that though the Pruſſian colour in this way readily decompoſed and ſeparated moſt of the adjective colours united to a ferruginous baſis, for which it has a ſtrong attraction, it had not any ſufficiently ſtrong for the aluminous baſis to ſeparate the colouring matters combined therewith: and hence in all caſes where a portion of alumine had been united with iron, to form the baſis or mordant, and an olive colour had been thus produced by weld or Quercitron bark either upon cottons, ſilk, or wool, a green invariably reſulted, from an application of the Pruſſian alkali with ſulphuric acid, unleſs where this acid was made to predominate ſo greatly as to decompoſe, even that part of the vegetable colouring matter which adhered to the aluminous part of the bafis. By reflecting upon thefe facts, I was led to a method of applying the Pruffian blue for dying upon woollen, filk, and cotton, which feems to me capable of obviating every difficulty hitherto attending its ufe for thefe purpofes. I have already mentioned Mr. Berthollet's opinion, that the inequality of colour to which the dying with Pruffian blue is liable, arifes from the difficulty of applying the ferruginous particles alone equally to all the fibres of the cloth; though this may be eafily done, when the particles of the iron are combined with thofe of different adjective vegetable colours; I therefore boiled up what I conceived to be fuitable proportions of copperas, with Quercitron bark, fuftic, and logwood feparately, and then dyed a piece of woollen cloth in each of thefe mixtures, by boiling it therein for ten or fifteen minutes; I chofe thefe vegetable dying drugs, without any regard to their particular colours, only becaufe they were cheaper than any others, regard being had to their proportions of colouring matter, and becaufe they do not contain any mixture of that particular fubftantive colouring matter found in galls, fumach, &c. which the Pruffian colour would be lefs capable of decompofing and difcharging. The pieces fo dyed being afterwards feparately immerfed in warm diluted pruffiate of pot-afh, neutralized by fulphuric acid, became all equally and beautifully blue. It muft, however, be obferved, that this does not always happen, becaufe when too much copperas is employed in the dying with Quercitron bark, &c. there will be an excefs of calx of iron applied to the fibres of the wool, which, from its rufty yellow colour, will give the Pruſſian blue a greeniſh tinge. This, however, may be readily diſcharged, by paſſing the cloth through warm water, ſlightly ſoured by muriatic acid; though a few experiments would be ſufficient to aſcertain exactly the quantity of copperas neceſſary for producing any particular ſhade of blue in this way upon any given quantity of cloth, and thereby obviate all difficulty on this point. It is neceſſary always to apply the Pruſſian colouring matter in a moderate heat, otherwiſe it will be precipitated by the ſulphuric acid, and rendered unfit for this purpoſe, unleſs diſſolved again by pot-aſh, lime, &c.

I ſhall offer ſomething more reſpecting the uſe of Pruſſian blue for dying *green* upon woollens, when I come to treat of the properties of Quercitron bark.

To aſcertain whether any affinity exiſted between the aluminous baſis and the colouring matter of Pruſſian blue, I took a piece of cotton which had been printed with the aluminous mordant, and cleanſed as uſual for topical dying, and immerſed it in warm diluted pruſſiate of pot-aſh; ſeeing, however, at the end of fifteen minutes that it had acquired no colour, I put into the liquor a ſmall proportion of a ſolution of iron by muriatic acid, which rendered it blue, and the cotton ſoon became of that colour pretty equally, without any manifeſt difference of colour in the places to which the aluminous mordant had been previouſly applied. Taking the cotton out of this dying liquor, I tore off a bit of it, and waſhed it with ſoap, which ſoon diſcharged all the colour, excepting where the cotton had been impregnated with alumine, and there it was conſiderably weakened, though enough remained to ſhow that it was attracted and rendered more fixed by the aluminous baſis. Another bit of the ſame cotton was immerſed in a ſolution of ammoniac, (vol-alkali,) which having a power of decompoſing the Pruſſian blue, I ſuppoſed it would weaken, if not wholly diſcharge the colour. To my ſurprize, however, I found it greatly augment the blue, which before had been rather pale, and give it almoſt the appearance of what is called garter blue; an effect which will perhaps be the leſs ſurprizing, if we conſider that volatile alkali, like the Pruſſian colouring matter, is an animal production, and compoſed of the ſame principles, excepting only the carbone, which it wants, and which exiſts in the latter.

Another bit of the ſame cotton being put into water, very ſlightly tinctured with a ſolution of copper by volatile alkali, the blue colour in a very ſudden and ſurprizing degree augmented to an intenſely deep garter blue or violet, much exceeding that produced by the ammoniac alone; and this being afterwards waſhed with ſoap, the colour of thoſe parts where the aluminous mordant had been at firſt applied, was ſtill better fixed than it had been on the like parts by the volatile alkali alone in the preceding trial.

Another piece of the ſame cotton being immerſed in water, with which a very little muriate of copper had been previouſly mixed, ſoon

became

became of a deeper blue, but without any of the purple or violet hue which had been produced in the two preceding inſtances.

This piece being afterwards waſhed with ſoap, I perceived that the colour where the aluminous mordant had been applied was ſtill much more firmly fixed than it had been by any other means. Indeed after a ſevere waſhing, which completely diſcharged the colour every where elſe, the ſpots or parts impregnated with alumine retained a full ſtrong blue, which the ſoap had indeed turned a little towards a violet colour; but after being well rinced in clean water, it returned again to its proper complexion, and ſtood a long expoſure to weather unaltered, and afterwards two or three ſevere waſhings with ſoap, without much diminution of colour *. It muſt, however, be remembered, that if copper thus manifeſtly fixed the Pruſſian blue, it was only in thoſe parts where the aluminous mordant had been at firſt applied; ſince the other parts of the cotton were waſhed white as ſoon as they were on the bit, to which nothing had been applied after it became blue; ſo that there can be no doubt but what both alumine and copper together greatly contribute to fix the colouring matter of Pruſſian blue. The copper indeed, as we ſhall preſently ſee, poſſeſſes a power of uniting therewith, and producing one of the

* In this and the other pieces the blue upon the ſpots impregnated with alumine, after it had been weakened by waſhing, was rendered nearly as ſtrong as ever, by dipping them into water ſlightly ſoured with ſulphuric acid, ſo as to decompoſe and neutralize the alkali which had been imbibed from the ſoap in waſhing.

moſt permanent of colours even upon linen and cotton; a fact which I believe never was imagined by any one, until it very lately fell under my obſervation. From theſe proofs of the utility of an aluminous baſis in fixing the Pruſſian blue, it probably would prove advantageous to prepare woollens by the uſual boiling with alum, or alum and tartar, before they are dyed with copperas and Quercitron bark, fuſtic, or logwood, for a Pruſſian blue. But in this caſe it will be neceſſary to mix a greater proportion of oil of vitriol in the pruſſiate of pot-aſh, or of lime, in order that there may be an exceſs of acid to aſſiſt in diſcharging theſe vegetable colouring matters, otherwiſe inſtead of a blue they would produce a green, or a black, where logwood had been employed with the copperas.

Having ſoaked pieces of ſilk and of cotton in the diluted pruſſiates of pot-aſh, ſoda, lime, and ammoniac, or volatile alkali, ſeparately, and afterwards dried them, I applied to each, by the pencil, a little of the ſolutions of all the metals and ſemi-metals in moſt of the different acids and alkalies, where they were ſoluble in the latter, in order to ſee the effects of all theſe ſeveral baſes upon the Pruſſian colouring matter. I ſhould tire the patience of my readers, were I particularly to deſcribe the reſults of theſe different combinations, eſpecially as no words can convey adequate ideas of the great variety of ſhades and degrees of colour, and particularly of the blue produced by them, and which varied prodigiouſly in its degrees of fullneſs and brightneſs, as well as in its inclination towards the purple and violet on one hand, and green on the other;

other; and indeed the diverſities of blue only, (which was the colour produced by much the greateſt number of metallic ſolutions,) would alone conſtitute a very pleaſing variety of colour in the way of printing upon ſilk or cotton. There were, however, ſeveral other colours produced at the ſame time; *e. g.* The nitro muriate of gold produced very beautiful green, inclining a little to the yellow, which, by waſhing, changed ſomewhat to the olive, whilſt the nitro-muriate of platina produced a green inclining to the blue. The muriate of tin, and the nitrate of mercury, produced greeniſh yellows, and the nitrate of nickle an olive brown. But the moſt remarkable, and probably the moſt uſeful effect of theſe applications, was, a very full, ſtriking, lively colour, of which I cannot by words give my readers a perfect idea, becauſe I do not remember to have ever before ſeen any colour exactly like it, and there is I believe no name in any language ſuited to it. It approaches neareſt, however, to the higheſt and brighteſt colour of new copper, but inclines more to the red, and is accompanied with a kind of metallic ſhining luſtre, which in my eyes appeared very agreeable. This colour (which I ſhall call the red copper colour, until a better name be given it) was produced by the different ſolutions of copper in the ſulphuric, the nitric, the muriatic, and the acetous acids ſeparately; and particularly well by that in volatile alkali. Copper, however, was not the only metallic baſis which produced this colour, though it was the cheapeſt, and therefore the moſt ſuitable for this purpoſe. The nitrates of ſilver and of cobalt produced exactly the ſame

colour

colour as the ſolutions of copper, and they all equally poſſeſſed the ſingular property of fixing the Pruſſian colouring matter ſo firmly to this red coppery hue, that, beſides reſiſting acids, no number of waſhings with ſoap, nor expoſure to weather for the longeſt ſpace of time, ſeem capable in the leaſt degree of diminiſhing either its body or its luſtre, and therefore I cannot help thinking that it may prove highly uſeful, and more eſpecially for calico-printing, by way of *topical* application upon cottons, and perhaps in dying cotton-yarn for ſtripes of muſlins, borders of handkerchiefs, &c. I have not experienced the ſame effect from a *direct* mixture of the Pruſſian colouring matter with a ſolution of copper, not even when I put the pruſſiate of ammoniac into a ſolution of copper by ammoniac (which I thought moſt likely to anſwer); but have always found it neceſſary either to apply the Pruſſian colouring matter (diſſolved by pot-aſh, ſoda, ammoniac, or lime) firſt to the linen, cotton, or ſilk, and after ſuffering it to dry, to apply ſome one of the before mentioned ſolutions of copper, ſilver, or cobalt; or elſe to apply the metallic ſolution firſt, and then the Pruſſian; but in this laſt method, I have not found any ſolution of copper anſwer ſo well, excepting that by the ammoniac, or volatile alkali.

Many of the other colours (beſides the coppery red laſt mentioned) which were produced on ſilk and cotton from the Pruſſian colour, and the different metallic ſolutions, ſtood ſeveral waſhings with ſoap, and particularly the blues, of different ſhades and complexions. They all

perfectly

perfectly refifted the impreffions of air; and it feems to me that they are capable of very ufeful applications in this way, and particularly fuited for a kind of printing or painting upon filk, which for this purpofe might be impregnated with a diluted colourlefs pruffiate of pot-afh, foda, or ammoniac, or with a pruffiate of lime, and made to receive a pleafing variety of colours from the different metallic folutions, applied either by the pencil or the block; and after drying, a farther addition of colours might be made, by rincing the filk in clean water, to carry off the Pruffian colour from the parts where it was not wanted, and make room for the application of many different fubftantive colours, which either have been or will be mentioned in the courfe of this work.

Similar applications might alfo be made to muflins; but in that cafe, as fome of the Pruffian colours would be liable to injury from foap, it would be proper to wafh them with bran or oatmeal in water. I ought farther to mention, that in fome inftances the fame metal diffolved by different acids does not produce the fame colour with the Pruffiate of pot-afh, &c. Thus, *e. g.* though the nitrates of filver and cobalt produce the red copper colour before defcribed, the muriates of thefe metals produce a blue, and though the nitrate of lead produces a ftrong lively blue, the muriate of that metal produces no colour with the pruffiates of lime, ammoniac, &c. To conclude this fubject, I fhall only add, that when I firft obferved the red copper colour produced as before mentioned, and experienced its fixed unalterable nature, I ftrongly fufpected that the

oxyd

oxyd of iron made a part of it, more especially as it had first occurred to me, when applying the ammoniate of copper to the prussiate of pot-ash; but I always found the same effect from the prussiates of ammoniac and lime, in which, by suitable means, I satisfied myself that no iron was held in solution; and I moreover found, that no solution of iron would produce any such effect with any of the solutions of copper.

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## CHAP. IX.

### *Of Adjective Colours from European and Asiatic Insects.*

> "La laine & la soie qui montreroient plutot dans leur "couleur naturelle la rusticité de l'age que l'esprit "de l'homme & la politesse du siecle, n'auroient "qu'un mediocre commerce si la teinture ne leur "donnoit des agréments qui les font rechercher & "desirer meme par les nations les plus barbares."
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> COLBERT, *Instruction generale pour la Teinture*, &c. 1672.

### ART. I.

THE kermes (Coccus Ilicis, Lin.) is an insect which the Greeks and Romans distinguished by the names of Coccus Baficus, Coccus Infectorius, Coccum Squarlatinum, Granum Tinctorium, &c. and which is found on a small species of oak (the Quercus Coccifera of Lin.) growing in most of the southern parts of Europe, as well as in many parts of Asia. According to Father Plumier, the Arabian name of this insect *kermen*, or *kermes*, signifies a little a little worm; and Pliny, though he conſidered it as the excreſcence of a tree, mentions it as ſpeedily becoming a worm: "Coccum Ilicis "celerime in vermiculum ſe mutans *."

This inſect appears to have been one of the moſt ancient of all dying drugs, and that which produced the colour originally known by the name of ſcarlet in England, as it had been by that of coccus among the Romans. Pliny indeed inaccurately deſcribes it as a kind of roſe colour, (coccus, qui in roſis micat,) whereas it is in fact a red, approaching nearly to that of florid arterial blood. Cteſias and Ælian alſo mention a crimſon colour produced from inſects, which probably were either the kermes or lacca inſects. Sir John Chardin, in an account of Perſia, (publiſhed in Harris's Voyages,) remarks, that in certain parts of Media "they "gather *cochineal*, though in no great quan- "tity, nor for any longer time than eight days "in ſummer, when the ſun is in Leo; for be- "fore that time the people (continues he) ſay "it doth not come to maturity; and after it, "the worm from which they draw the cochineal "makes a hole in the leaf in which it grows, "and is loſt. The Perſians call cochineal "kermes, from kerm, which ſignifies a worm, "becauſe it is extracted out of worms." But in this inſtance the term cochineal, which belongs peculiarly to an American inſect, is very improperly applied to the kermes.

The firſt volume of the Philoſophical Tranſactions contains a paper, written by M. Verney,

* Lib. xxiv. ſect. 4. fol. 327.

then

then of Montpellier, refpecting the Natural Hiftory of the Kermes; and M. Reaumur afterwards defcribed them very minutely in the fourth volume of his "Memoires pour fervir "a l'Hiftoire des Infectes." But the moft ufeful information on this fubject feems to be that which M. Chaptal lately gave to M. Berthollet, and which he has publifhed in the fecond Volume of his Elemens de l'Art de la Teinture. The male infect paffes from its vermicular ftate through the ufual forms into that of a fly with four wings; though the female never acquires any wings, but fixes herfelf on a leaf of the oak, where, being impregnated by the male, her fize gradually increafes (as the eggs enlarge) to that of a juniper-berry, and fhe at the fame time becomes of a reddifh brown colour. When the eggs are on the point of hatching, the females fhould be collected and expofed to the fteam of vinegar, to kill them and prevent their young from being brought forth; and afterwards they fhould be dried by being fpread out on cloths, by which treatment they acquire the colour of red wine. M. Chaptal fays, that a fingle perfon may collect from one to two pounds of kermes in a day. Formerly very great quantities of thefe infects were gathered, particularly in the fouthern parts of France and Spain, for dying; but their ufe in this way has been almoft wholly fuperfeded, at leaft in Europe, by that of the cochineal, which affords a more beautiful, and even a cheaper colour, fince one pound of the latter will dye as much as twelve pounds of kermes, which probably could not be now had in any quantity for lefs than half a crown the pound. But the kermes red or fcarlet, though lefs vivid, is more durable than that of cochineal, and much lefs liable to be changed by foap, acid, mud, &c. The fine blood reds feen at this time on old tapeftries in different parts of Europe, unfaded, though many of them are two or three hundred years old, were all dyed from kermes, with the aluminous bafis, on woollen yarn.

To prepare wool for the kermes dye, it is to be boiled in water, with about one-fifth of its weight of alum, and half as much of tartar, for the fpace of two hours, and afterwards left in the fame liquor four or five days, when being rinced, it is to be dyed in the ufual way, with about twelve ounces of cochineal, for every pound of wool. Scarlets, &c. given from kermes, were called *grain colours*, becaufe that infect was miftaken for a grain; and afterwards the fame appellation was for the fame reafon given to cochineal colours.

Wool prepared with a nitro-muriatic folution of tin, (as is now practifed for the cochineal fcarlet,) and dyed with kermes, takes a kind of aurora, or reddifh orange colour. Cotton prepared with the printer's aluminous mordant, and dyed with kermes, exhibits a fine red, inclining to the crimfon fhade; but this will gradually, though flowly difcharge, and the colour be weakened in wafhing.

I had formerly made fome experiments which feemed to promife fuccefs in fixing the colour of kermes more permanently on cotton; and wifhing to repeat and extend them, I endeavoured

to

to procure kermes fufficient for this purpofe; but finding none in Great Britain, I have taken fteps to fecure a fupply from the fouth of France, which however not being yet come to hand, I fhall defer what I may have farther to communicate on this fubject, until the publication of my next volume.

Art. II. Lacca, or gum lac, is brought from different parts of the Eaft Indies, and in different forms. In its natural ftate it adheres externally to the fmall branches of certain fhrubs, and is then called ftick lac. When feparated from the fticks, and garbled, it is denominated *feed lac*; and this liquefied by heat, and formed into cakes, is called *lump lac*. Seed lac, deprived of its colouring matter, by being boiled in hot water, then liquefied by heat, ftrained, and formed into thin tranfparent plates, becomes *fhell* lac*. Gum lac is the production of certain little infects of the coccus genus, of which the firft account deferving our notice feems to have been that communicated by Mr. James Kerr of Patna, (through Sir Jofeph Banks,) to the Royal Society, and publifhed in the Philofophical Tranfactions for 1781. According to Mr. Kerr's defcription of the coccus lacca, when firft brought forth in November and December, "the head and trunk form one uniform oval "compreffed *red* body, of the fhape and mag-

* Sir William Jones fays, "the Hindus have fix names "for Lac; but they generally call it Lácfhà, from the "multitude of fmall infects, who, as they believe, difcharge "it from their ftomachs, and at length deftroy the tree on "which they form their colonies." Differtations, &c. relating to the Hiftory and Antiquities, &c. of Afia, vol. ii.

"nitude

" nitude of a very ſmall louſe, conſiſting of
" twelve tranſverſe rings; the back is carinate,
" the belly flat, the antennæ half the length of
" the body, fili-form, truncated and diverging,
" ſending off two, ſometimes three delicate di-
" verging hairs longer than the antennæ."
The tail is " a little white point, ſending off
" two horizontal hairs, as long as the body."
The inſect had three pair of limbs half of its
own length, but no wings were ſeen by Mr.
Kerr. As ſoon as they are brought forth, the
inſects begin to " traverſe the branches of the
" trees upon which they were produced for
" ſome time, and then fix themſelves upon the
" ſucculent extremities of the young branches.
" By the middle of January they are all fixed
" in their proper ſituations, and appear as plump
" as before, but ſhew no other marks of life.
" The limbs, antennæ, and ſetæ of the tail, are
" no longer to be ſeen. Around their edges
" they are environed with a ſpiſſed ſubpellucid
" liquid, which ſeems to glue them to the
" branch. It is the gradual accumulation of
" this liquid which forms a complete cell for
" each inſect, and is what is called gum lacca.
" About the middle of March the cells are
" completely formed, and the inſect is in ap-
" pearance an oval ſmooth red bag, without
" life, about the ſize of a ſmall cuchanical in-
" ſect, emarginated at the obtuſe end, full of a
" beautiful *red liquid*. In October and No-
" vember we find about twenty or thirty oval
" eggs, or rather young grubs, within the red
" fluid of the mother. When this fluid is all
" expended, the young inſects pierce a hole

Q " through

" through the back of their mother, and walk " off one by one, leaving their exuviæ be- " hind."

According to Mr. Kerr, the lacca insects in the country where he wrote were found on four species of shrubs: 1st, Ficus Religiosa, Lin. 2d, Ficus Indica, Lin. 3d, Plaso Hortus Malabaraci; and, 4th, Rhamnus Jujuba, Lin.—They fix themselves in such multitudes on the branches of these trees, and more especially of the three first, that " the extreme branches ap- " pear as if they were covered by a red dust; " and their sap is so much exhausted, that they " wither and produce no fruit." Birds perching on these branches carry off great numbers of the lacca insects, adhering to their feet, and transplant, by depositing them on other trees where they rest.

" The gum lacca of this country (says Mr. " Kerr) is principally found upon the unculti- " vated mountains on both sides of the Ganges, " where bountiful nature has produced it in " such abundance, that were the consumption " ten times greater than it is, the markets " might be supplied by this minute insect. " The only trouble in procuring the lac is in " breaking down the branches, and carrying " them to market. The present price in Dacca " is about 12s. the 100lb. weight, although it " is brought from the distant country of Assam. " The best lac is of a *deep red* colour. If it be " pale, and pierced at the top, the value di- " minishes, because the insects have left their

" cells,

" cells, and consequently they can be of no use " as a dye or colour:" though the lac itself may be better for varnishes.

The lacca is capable of being applied to several uses. That of dying, however, is alone the object of our present inquiry; and for this it appears to have been known and employed by the ancients. (See Salmas. Exercit. p. 810.)

By Mr. Kerr's account, the native Indian inhabitants, after extracting the colouring matter of the lac by hot water, mix alum and tamarind water with the decoction, and dye silk and cotton therein.

Of the four species of shrubs upon which the lacca insects are found in the countries adjacent to Patna, according to Mr. Kerr, there is only one, the Rhamnus Jujuba, upon which Dr. James Aderson found these insects near Madras, though he observed them on several species of Mimosa, and on some other trees and shrubs. Dr. Roxburgh, of Samulcotta, seems to think, however, that on the coast of Coromandel they only inhabit shrubs of the Mimosa kind, and even but three species of this genus. He says, (see Philos. Trans. 1791,) that " some pieces " of fresh looking lac adhering to small branches " of the Mimosa cinerea, Lin. were brought " to him on the 20th of November 1789;" and being carefully kept in wide-mouthed crystal bottles, slightly covered, after fourteen days had elapsed " thousands of exceeding minute " red animals were observed crawling about the "lac and the branches it adhered to, and ſtill "more were adhering to the ſurface of the cells. "By the aſſiſtance of glaſſes, ſmall imperforated "excreſcences were alſo obſerved interſperſed "among the holes; two regularly to each hole, "crowned with ſome very fine white hairs, "which being rubbed off, two white ſpots ap- "peared. The animals, when ſingle, ran "about pretty briſkly; but in general on open- "ing the cells they were ſo numerous as to be "crowded over one another.

"The ſubſtance of which the cells were form- "ed, cannot be better deſcribed, (ſays Dr. Rox- "burgh,) with reſpect to appearance, than by "ſaying, that it is like the tranſparent amber "that beads are made of. The external co- "vering of the cells may be about half a line "thick, is remarkably ſtrong, and able to reſiſt "injuries; the partitions are much thinner. "The cells are in general irregular ſquares, "pentagons and hexagons, about an eighth of "an inch in diameter, and a quarter of an inch "deep: they have no communication with each "other. All thoſe I opened during the time "the animals were iſſuing from them, con- "tained in one ſide, which occupied half the "cell, a ſmall bag filled with a thick red jelly, "like liquor, replete with what I take to be "the eggs. Theſe bags, or utriculi, adhere to "the bottom of the cells, and have each two "necks, which paſs through perforations in the "external coat of the ſhells, forming the before- "mentioned excreſcences, ending in ſome fine "hairs.

"The

"The other half of the cells has a diſtinct "opening, and contains a white ſubſtance, like "ſome filaments of cotton rolled together, and "a number of the little red inſects themſelves, "crawling about, ready to make their exit. "Their portion of each cell is about one half, "and I think muſt have contained near one "hundred of theſe animals. Other cells leſs "forward, contained in this half, with one "opening, a thick, red, dark, blood-coloured "liquor, with numbers of exceedingly minute "eggs, many times ſmaller than thoſe found in "the ſmall bags which occupied the other half "of the cells."

Dr. Roxburgh deſcribes the circumſtances and progreſs of theſe inſects, and particularly the females, through the larva and pupa onwards, to their perfect ſtates, which laſt they did not reach until near five months. The male inſect in the perfect ſtate was about the ſize of a very ſmall fly, and exceedingly active; with an obtuſe head, black eyes, oval brown trunk, ſix legs for running and jumping, and four membranaceous incumbent wings, of which the anterior pair was twice as long as the poſterior; but he had no tail.

The female inſect, in her perfect ſtate, was rather ſmaller than the male, and of a brighter red colour, though leſs active. Her head and eyes were very ſmall; trunk red, and almoſt aubicular; abdomen red, oblong, and compoſed of twelve annular ſegments; ſhe had ſix legs for running and jumping, with only two long tranſparent incumbent wings, and a tail confifting of two white hairs as long as her body.

" The eggs, and dark-coloured glutinous li-
" quor they are found in, (continues Dr. Rox-
" burgh,) communicate to water a moft beau-
" tiful red colour, *while frefh*. After they have
" been dried, the colour they give to water is
" lefs bright; it would therefore be well worth
" while for thofe who are fituated near places
" where the lac is plentiful, to try to extract
" and preferve the colouring principles by fuch
" means as would prevent them from being in-
" jured by keeping. I doubt not but in time a
" method may be difcovered to render this co-
" louring matter as valuable as cochineal.

" Mr. Hellot's procefs (adds Dr. Roxburgh)
" for extracting the colouring matter from dry
" lac, deferves to be tried with the frefh lac,
" in the month of October or beginning of
" November, before the infects have acquired
" life; for I found the deepeft and beft colour
" was procured from the eggs while mixed with
" their nidus. His procefs is as follows: Let
" fome powdered gum lac be digefted two hours
" in a decoction of comfrey root, by which a
" fine crimfon colour is given to water, and the
" gum is rendered pale or ftraw coloured. To
" this tincture, poured off clear, let a folution
" of alum be added; and when the colouring
" matter has fubfided, let it be feparated from
" the clear liquor and dried. It will weigh
" about one-fifth of the quantity of lac em-
" ployed. This dried fecula is to be diffolved
" or diffufed in warm water; and fome folution
" of

" of tin is to be added to it, by which it ac-
" quires a vivid ſcarlet colour. This liquor is
" to be added to a ſolution of tartar in boiling
" water, and thus the dye is prepared.

" In India (ſays Dr. Roxburgh) comfrey roots
" are not to be had; but any other mucilaginous
" root, gum, or bark, would probably anſwer
" equally well. On ſome parts of the Coroman-
" del coaſt, if not over it all, a decoction of the
" ſeeds of a very common plant, (Caſſia Tora
" of Linnæus,) which is extremely mucilagi-
" nous, is uſed by the dyers of cotton cloth blue,
" to help to prepare the blue vat. It *ſuſpends*
" the indigo until a fermentation takes place to
" diſſolve it, and alſo helps to bring about that
" fermentation earlier than it otherwiſe would."

Probably ſome methods of extracting the colouring matter of freſh lac, ſimilar perhaps in a conſiderable degree to that propoſed by Dr. Roxburgh, have been already attempted in ſome parts of India. A gentleman, to whom I have already had occaſion to allude ſeveral times, lately received from Bengal, where he had formerly reſided, a parcel of a colouring matter, which had very much the appearance of powdered cochineal, of which he gave me a few ounces, calling it Eaſt-Indian Cochineal, with a requeſt that I would try its effects in dying ſcarlet. I happened then to have by me a piece of cloth which I had previouſly prepared for receiving a ſcarlet from cochineal, (upon a new principle to be hereafter explained,) by impregnating it with a muriatic ſolution of tin, and a certain portion of yellow colour from the Quercitron bark; and I reſolved to ſee whether this Eaſt-Indian colouring matter would yield a crimſon, capable, when fixed as a dye in the cloth ſo impregnated and made yellow, of producing a ſcarlet, as the natural crimſon of cochineal would do by the ſame means. But on boiling the cloth in queſtion with this Eaſt-Indian colouring matter in water, I found it wholly inſoluble by this menſtruum. However, upon taking out the cloth, and adding a little pearl-aſh, the water immediately aſſumed a fine crimſon colour, the alkali having, as I afterwards diſcovered, ſeparated the colouring matter from a portion of alumine which had been employed to precipitate it (in India), and to which it was too intimately united to be diſſolved by water only. Having thus obtained an alkaline ſolution of the colouring matter in queſtion, I decanted off the clear crimſon liquor, added to it a little muriate of tin, principally to neutralize the alkali, and precipitate any alumine which might have been diſſolved by it, and then dyed the piece of cloth before mentioned, which took a very good ſcarlet, much better indeed than I have ever been able to give from the lac brought to this country in its natural form; though from many circumſtances and ſubſequent trials, I am fully perſuaded that the colouring matter which produced this effect, was in reality nothing but the colouring matter of lac, extracted either when freſh, or by ſome particular means when dried, and afterwards precipitated either wholly or in part by alum.

A few years ſince, ſome perſons in this country formed an eſtabliſhment for extracting the colouring

colouring matter of dried lac; but it probably did not ſucceed according to their expectations, ſince it does not I believe now ſubſiſt. An extract, anſwering tolerably well, may be made from this drug, by merely boiling it in water, ſtraining off the coloured liquor, and evaporating it to a ſolid conſiſtence. The cells which contain the lacca inſects, and the matter of which they are compoſed, as well as the uſes to which they are ſubſervient, ſeem analogous in many reſpects to the honey-comb, &c. of bees. The fine red-coloured liquor contained in the cells of the lac is alſo deſcribed by ſome authors as being ſweet to the taſte, at the ſame time that it readily mixes with water. Great uſe is made of it as a dye by the natives of Aſſam.

The colours dyed by ſtick lac approach very nearly to thoſe of cochineal. They are indeed not quite ſo lively and beautiful, but this defect is in ſome degree compenſated by their being more durable, eſpecially on cottons, where I have employed it with ſome ſucceſs topically, with different baſes. It has been ſometimes a practice to employ a mixture of the colouring matter of lac, with that of cochineal, in producing ſcarlets, &c. Both require the ſame baſis, and nearly the ſame treatment, which will be fully deſcribed in the chapter reſpecting the uſes of cochineal. At preſent, however, almoſt all the lacca brought to Europe is afterwards ſent to Portugal, Barbary, &c. and employed in ſtaining goat ſkins to produce what is called red Morocco leather.

Art. III. The Coccus tinctorius Polonicus is a ſmall round inſect very much reſembling the kermes in many reſpects. It uſed to be collected, in conſiderable quantities, in the Ukraine and other provinces of Poland, as well as in the Great Dutchy of Lithuania, from about the roots of the German knot-graſs or knawel (Scleranthus perennis, Lin.). The male only, by a transformation ſimilar to that of the male kermes, becomes a fly, though with but two wings, which are white, edged with red. The females, being impregnated by the male, enlarge their ſize, and become ready to bring forth their young ſoon after the ſummer ſolſtice, at which time they abound moſt in a crimſon juice, which was formerly very much uſed by the Turks and Armenians in dying wool, ſilk, and hair, as well as in ſtaining the nails of women's fingers. But the uſe of theſe inſects, like that of kermes, has been nearly laid aſide every where, ſince the cheaper and more beautiful colours of cochineal have become generally known. This dye was fixed on wool and ſilk by the uſual mordant or preparation of alum and tartar.

Very ſimilar to the Coccus Polonicus is an inſect, which in many parts of Europe was formerly taken from the roots of the burnet, (Poterium Sanguiſorba, Lin.) and which was uſed in different countries, and particularly by the Moors, for dying wool and ſilk of a crimſon or roſe colour. Ray, deſcribing this plant, ſays, "Hujus radicis adnaſcitur quibuſdam in locis "*granum rubrum*, quo utuntur tinctores ad co-"lorem

"lorem carmesinum, unde sunt qui pro cocco "habent, & coccum radicum appellant monen- "tibus lacuna & anguillara." Hist. Plant. 401.

The Coccus Uvæ Ursi of Lin. is also an insect affording a fine red colour, capable of being employed adjectively in dying. It very much resembles the Coccus Polonicus, as well in its properties as in its form, but with this advantage, that it is nearly twice as large.

M. Olivier, in his "Entomologie," &c. says, the *meloë proscarabé* might furnish a colour useful to dyers and painters; and that some things of this sort might be obtained from a considerable number of the *coleopteres*.

In the next chapter I shall have occasion to mention another insect lately sent from India, and mistaken there for cochineal, with which I dyed a very durable chocolate colour; and probably there are many others capable of being applied in this way.

CHAP.

## CHAP. X.

### *Of the Natural Hiſtory of Cochineal.*

" Our vallies yield not, or but ſparing yield
" The dyers' gay materials. Only weld,
" Or root of madder, here, or purple woad,
" By which our naked anceſtors obſcur'd
" Their hardy limbs, inwrought with myſtic forms
" Like Egypt's obeliſks." DYER.

THE Cochineal, or Coccus Caċti of Linnæus, is arranged among the "Inſecta" of the fifth claſs of that great naturaliſt; and in the ſecond order, comprehending the "Hemiptera," (half-winged inſects, &c.) The body of the male is ſlender, of a red colour, covered by two wings, ſpread horizontally, and croſſing each other a little on the back, and enabling him to fly or rather flutter. The head is diſtinct but ſmall, with two diverging ſlender antennæ; the abdomen or tail is terminated by two ſmall and very long diverging hairs; he has ſix feet, with which he ſometimes jumps like the lacca inſect; and hence Linnæus has applied the term "ſaltatoria," as one of his diſtinguiſhing characters. The male inſects are but ſeldom found among the cochineal ſent to Europe. The back of the female is hemiſpherical, and croſſed by numerous wrinkles; ſhe is of a dark reddiſh brown colour; her mouth is a ſmall tubular projection from the thorax; ſhe is without wings, but has ſix legs; theſe, however, only ſerve her to remove during a ſhort interval imme-

immediately ſucceeding her birth; after which they become uſeleſs, and ceaſing to grow from inactivity, remain ſo ſmall as to be afterwards hardly perceptible, at leaſt without a very minute inſpection. This circumſtance probably occaſioned, and certainly confirmed, the belief which prevailed very generally in Europe, during a conſiderable number of years, that theſe inſects were vegetable grains or ſeeds.

The cochineal is nouriſhed, perhaps excluſively, by ſome of the different ſpecies of the *Cactus*, or Indian fig, (called by ſome the prickly pear,) a genus of plants, of which Linnæus deſcribes twenty-five ſeveral ſpecies, all originally found in America only; of very different forms, and producing fruits of various colours when ripe, according to the ſpecies on which they reſpectively grow; as white, yellow, red, crimſon, purple, violet, green, &c. Among theſe, the red and crimſon coloured fruits more eſpecially contain a mucilaginous juice, which communicates the colour of the fruit in a high degree to the urine of thoſe by whom it is eaten. That ſpecies on which the cochineal attains its greateſt perfection, is denominated Cactus Cochenillifer by Linnæus. But the inſects live naturally, in their wild ſtate at leaſt, on ſome of the other ſpecies, particularly the Cactus tuna, Cactus opuntia, and Cactus pereſkia; all of which, as well as the Cactus cochenillifer, belong to that ſection of Cacti which Linnæus diſtinguiſhes as "opuntiæ compreſſæ, articulis "proliferis," *i. e.* flattened or compreſſed with prolific articulations. The Cactus cochenillifer, however, which the Mexican Spaniards call nopal,

pal, is alone cultivated for the purpoſe of feeding and breeding theſe inſects.

The Spaniards, on their firſt arrival in Mexico, ſaw the cochineal employed, as it appears to have been long before, by the native inhabitants of that country, in colouring ſome parts of their habitations, ornaments, &c. and in ſtaining their cotton; and being ſtruck with its beautiful colour, they gave ſome accounts of it to the Spaniſh miniſtry, who in the year 1523 (as Herrara informs us) ordered Cortes to take meaſures for multiplying this valuable commodity; but as the Spaniards then in America were careleſs of every thing but gold and ſilver, they left this object to the induſtry of the natives only; which, however, from the large ſupplies ſoon after ſent to Europe, appears to have been ſucceſsfully exerted in this reſpect.

For a number of years the inhabitants of Europe were generally miſtaken reſpecting the nature and origin of cochineal, ſuppoſing it to be grain or ſeed, as has been already obſerved. The firſt opinion to the contrary was, I believe, given by the anonymous author of a paper, in the third volume of the Philoſophical Tranſactions, (printed in the year 1668,) in which he ſuppoſes cochineal to be an inſect "*engendered*" by the fruit of the prickly pear; and being a believer of equivocal generation, he propoſes to employ fermentation as a means of engendering and multiplying theſe inſects more copiouſly.

In the year 1672, a paper written by Liſter was publiſhed in the ſeventh volume of the Philoſophical

losophical Transactions, concerning the kermes, in which he "conjectures cochineal may be a "sort of kermes." The seventeenth volume of the Transactions, published in 1691, contains some observations concerning the making of cochineal, according to a relation had from an old Spaniard at Jamaica, who says, "cochineal "is the same which we call lady bird, alias cow "lady, which at first appears like a small blis- "ter or little knob upon the leaves of the "shrub on which they breed, and which after- "wards, by the heat of the sun, becomes a live "insect as above, or a small grub."

Early in 1693, Father Plumier wrote and subscribed a declaration, which he delivered to Pomet, affirming cochineal to be an insect living on the opuntia or Indian fig, and that he had seen it in the island of St. Domingo; and de Laet had some little time before described it as feeding on the tuna. Pomet, however, misled by the prevailing opinion on this subject, as well as by several letters which about that time were sent to him from St. Domingo by F. Rousseau, adopted the fallacious accounts of this letter-writer, (who promised to send over to France some of the very plants whose seeds, as he asserted, afforded the true cochineal,) and described this drug as the seed of a plant two or three feet high, bearing pods of a conical form, in which the cochineal grew naturally. (See Hist$^{e}$ Gen$^{e}$ des Drogues, &c.)

But groundless as this account was in reality, it obtained so much credit, that no longer than four years ſince, a very eminent dyer of this metropolis ſeriouſly told me, that having bought a large parcel of cochineal, he actually found among it one of theſe conical pods, containing cochineal naturally attached to the inſide like ſeeds.

Lewenhoek, however, by his glaſſes plainly ſaw that the cochineal was an inſect with ſix legs; and in a letter, read at the Royal Society the 21ſt of March 1704, and publiſhed in the xxivth volume of the Tranſactions, he poſitively contradicted all thoſe who had repreſented it as a vegetable grain; and declared that, by diſſections, he had invariably found eggs, or animalcula, in the ſuppoſed grains, and often to the amount of two hundred in each. He alſo repreſents theſe inſects as "not produced "from worms," but as "at once bringing "forth their like."

About the year 1730, Dr. Rutly, then Secretary of the Royal Society, publiſhed a Natural Hiſtory of Cochineal, (in the xxxvith volume of the Tranſactions,) from a work on this ſubject by Melchior de la Ruuſcher, who had procured from Antiquera in New Spain, the depoſitions of eight perſons, who had been actually employed for many years in the breeding and management of cochineal, and who ſwore that they were "ſmall living animals with "a beak, eyes, feet," &c. and the originals of theſe depoſitions, notarially authenticated, were depoſited in the archives of the Royal Society. Not long after this, Reaumur, in his Hiſt^e des Inſectes, Infectes, and Dr. Brown, in his Hiftory of Jamaica, defcribed the female cochineal with fufficient accuracy; as did Linnæus fome time after, from a living female fent to him by Mr. Rolander from Surinam, in the year 1756; though neither of thefe naturalifts had ever feen the male cochineal.

About the beginning of the year 1757, Mr. John Ellis, F. R. S. hearing that the cochineal infect bred in great abundance on the cactus opuntia in South Carolina and Georgia, wrote to Dr. Alexander Garden of Charleftown, South Carolina, for fome of the joints of that plant, with the infects thereon, which were accordingly fent the latter end of that year, and laid before the Royal Society. "Thefe fpecimens (fays "Mr. Ellis) were full of the nefts of this in-"fect, in which it appeared in its various ftates, "from the moft minute, when it walks about, "to the ftate when it becomes fixed and wrapt "up in a fine web, which it fpins about it-"felf.

"In order to find out the male fly, (conti-"nues he,) I examined all the webs in thefe "fpecimens, befides a large parcel which the "doctor had fent me picked off from the plants "in Carolina, and at laft difcovered three or "four minute dead flies with white wings. "Thefe I moiftened in weak fpirit of wine, and "examining them in the microfcope, I difco-"vered their bodies to be of a bright red co-"lour, which convinced me of their being the "true male infect. To be confirmed in my

 "opinion,

" opinion, I immediately communicated my " discovery to Dr. Garden, which I accompa- " nied with an exact microscopical drawing, and " desired he would send me some account of " their œconomy, with some male insects of his " own collecting," which he did in the spring of the year 1762, accompanied with the following observations:

" In August 1759, (says Dr. Garden,) I " catched a male cochineal fly, and examined " it in your aquatic microscope. It is seldom " a male is met with. I imagine there may be " one hundred and fifty or two hundred females " for one male. The male is a very active " creature, and well made, but slender in com- " parison of the females, who are much larger " and more shapeless, and seemingly lazy, tor- " pid, and inactive. They appear generally so " overgrown, that their eyes and mouth are " quite sunk in their rugæ or wrinkles; nay " their antennæ and legs are almost covered by " them, and are so impeded in their motions " from these swellings about the insertions of " their legs, that they can scarce move them, " much less move themselves.

" The male's head is very distinct from the " neck: the neck is much smaller than the head, " and much more so than the body. The thorax " is elliptical, and something larger than the " head and neck together, and flattish under- " neath; from the front there arise two anten- " næ, (much longer than those of the females,) " which the insect moves every way very brisk-

" ly.

" ly. These antennæ are all jointed, and from " every joint there come out four short setæ, " placed two on each side.

" It has three jointed legs on each side, and " moves very briskly and with great speed. " From the extremity of the tail there arise two " long setæ or hairs four or five times the length " of the insect. They diverge as they lengthen, " are very slender, and of a pure snow white " colour. It has two wings, which take their " rise from the back part of their shoulders or " thorax, and lie down horizontally, like the " wings of the common fly, when the insect is " walking. They are oblong, rounded at the " extremity, and become suddenly small near " the point of insertion. They are much longer " than the body, and have two long nerves; " one runs from the basis of the wing along the " external margin, and arches to meet a slender " one that runs along the under and inner edge. " They are quite thin, slender, transparent, and " of a snowy whiteness. The body of the male " is of a lighter red than the body of the female, " and not near so large."

To Dr. Garden's description, Mr. Ellis, in an account of the male and female cochineal insects, accompanied with drawings, &c. (in the fifty-second volume of the Philosophical Transactions,) adds, that the female has a remarkable proboscis or awl-shaped papilla, arising in the midst of the breast, which Linnæus calls the rostrum, and thinks it the mouth; " if so, (says " Mr. Ellis,) besides the office of supplying it " with nourishment during the time of its mov-

"ing about, it is the tube through which the "fine double filament proceeds, with which it "forms its delicate web, in order to accommo- "date itſelf in its torpid ſtate, during its preg- "nancy, till the young ones creep out of its "body, ſhift for themſelves, and form a new "generation.

"In this torpid ſtate the legs and antennæ "grow no more, but the animal ſwells up to "an enormous ſize, in proportion to its minute "creeping ſtate. The legs, antennæ, and pro- "boſcis, are ſo ſmall with reſpect to the reſt of "the body, that they cannot be eaſily diſco- "vered, without very good eyes or magnify- "ing glaſſes, ſo that to an indifferent eye "it looks full as much like a berry as an "animal.

"As ſoon as the female is delivered of its "numerous progeny, it becomes a mere huſk "and dies; ſo that great care is taken in Mex- "ico, where it is principally collected, to kill "the old ones while big with young, to prevent "the young ones eſcaping into life, and depriv- "ing them of that beautiful ſcarlet dye, ſo much "eſteemed by all the world."

It is proper here to obſerve, that there are two ſorts or varieties of cochineal; the beſt or do- meſticated, which the Spaniards denominate *grana fina*, or fine grain; and the wild, which they call *grana ſylveſtra*. The former is nearly twice as large as the latter, probably becauſe its nature has been improved by the favourable ef- fects of human care, and of a more ſuitable nouriſhment,

nouriſhment, derived ſolely from the cactus cochenillifer during many generations. But it is only from the wild cochineal, living naturally on ſome of the *opuntiæ*, in different parts of America, that the deſcriptions of Brown, Linnæus, and Ellis, were taken. It muſt alſo be obſerved, that the grana ſylveſtra are not only ſmaller than the others, but that their bodies are covered by very fine white downy filaments, which they ſpin to defend themſelves againſt cold, rain, &c. in their wild ſtate; but which adding to their weight, whilſt it yields no colour, contributes with other cauſes to render them leſs valuable.

In the month of January 1777, Monſ. Thiery de Menonville left Port au Prince, in the iſland of St. Domingo, for the purpoſe of procuring ſome of the living cochineal inſects in Mexico, and bringing them from thence, to be afterwards propagated in the French Weſt-India iſlands: an enterprize, for the expence of which four thouſand livres had been allotted by the government. He proceeded by the Havannah to La Vera Cruz, where he was informed that the fineſt cochineal inſects were produced at Guaxaca, diſtant about ſeventy leagues. Pretending ill health, he obtained permiſſion to uſe the baths of the river Magdalen; but inſtead of going thither, he proceeded through various difficulties and dangers, as faſt as poſſible, to Guaxaca, where, after making his obſervations, and obtaining the requiſite informations, he affected to believe that the cochineal inſects were highly uſeful in compoſing an ointment for his pretended diſorder (the gout), and therefore purchafed a quantity of nopals, covered with thefe infects, of the fine or domeftic breed, and putting them into boxes with other plants, for their better concealment, he found means to get them away as botanic trifles, unworthy of notice; and being afterwards driven by a violent ftorm into the bay of Campeachy, he there found and added to his collection a living cactus, of a fpecies which was capable of nourifhing the fine domefticated cochineal; after which, departing for St. Domingo, he arrived fafe, with all his acquifitions, on the 25th of September, (in the fame year,) at Port au Prince, where he began immediately to form a plantation of nopals, and to take fteps for propagating the two forts or varieties of cochineal, I mean the domefticated or fine, and the fylveftra or wild, which laft he found at St. Domingo, foon after his return, living naturally on the cactus perefkia. But unfortunately for this eftablifhment, he died in the year 1780, through difappointment and vexation, at feeing his patriotic endeavours fo little affifted, and his fervices fo fparingly rewarded by the government. Mr. Thiery de Menonville's labours being thus terminated, the Royal Society of Arts and Sciences at Cape Francois, having collected his papers, compofed from them a treatife on the cultivation of the nopals, and the breeding of cochineal, &c. of which Mr. Berthollet has given an extract in the fifth volume of the Annales de Chymie, together with an account of his own experiments, for afcertaining the effects of the grana fylveftra, produced at St. Domingo, compared with thofe from Mexico in dying.

From

From the obſervations of Mr. Thiery de Menonville, it appears that there are two varieties of the nopal, or cactus cochenillifer, growing in Mexico, one called the True Nopal of the Garden of Mexico, and the other the Caſtilian Nopal, a name given to the laſt of theſe varieties on account of its ſingular beauty. It appears alſo that the wild cochineal, or grana ſylveſtra, when reared upon either of theſe varieties of the nopal, become almoſt as large as the fine or domeſticated ſort, and loſe the greateſt part of thoſe fine downy filaments with which they are naturally covered, and which contribute to render them leſs valuable than the latter.

But beſides the advantage of affording the moſt ſuitable nouriſhment to cochineal, the nopals have another of very great importance, where theſe inſects are to be raiſed as objects of commerce; which is, that they are not beſet with thorns or prickles, like moſt of the cacti, and particularly the opuntia, tuna, and pereſkia, which by this circumſtance render the inſects nouriſhed upon them almoſt inacceſſible to any who might wiſh to collect them: Whilſt the true nopal, and that of Caſtile, have none but ſoft inoffenſive thorns, and the nouriſhment which they afford is at the ſame time ſo peculiarly well ſuited to the cochineal, and eſpecially to the fine or domeſticated ſort, that theſe laſt, though they can ſubſiſt on ſome, will proſper on no other ſpecies of cactus; and indeed the wild ſort, though found naturally upon ſeveral other ſpecies of opuntia, are at preſent raiſed chiefly on the nopals in Mexico. The young inſects, whilſt contained within the mother, appear to be all connected *one after the other* by an umbilical cord to a common placenta, and in this order they are in due time brought forth as living animals, after breaking the membrane, in which they were at firft probably contained as eggs. Being thus brought forth, they remain in a clufter under the mother's belly for two or three days, until difengaged from the umbilical cord; after which the females, for the only time of their lives, exercife their loco-motive faculties, by creeping to proper fituations on the plant; and in doing this they are led by a wife inftinct, to prefer the under-fides of the different branches or articulations, (as being moft defended from wind and rain,) where each attaches herfelf, by inferting her little tubular probofcis or mouth into the bark, and thus remains fixed to the end of life. By this infertion the female draws out for her nourifhment the colourlefs mucilaginous juice of the nopal, and foon becomes covered with a fine adhefive downy fubftance. The male acquires a fimilar covering, but quits it at the end of a month, and in the fhape of a little fcarlet fly, jumps and flutters about for the purpofe of copulation; and having thereby fecured a future progeny, he dies almoft immediately after. But the female having other duties to perform, outlives the male another month; at the end of which fhe is ready to bring forth her young, and this is the precife time for gathering thofe which are not wanted for breeding, and this is done by preffing the dull blade of a knife between the under furface of a branch of the nopal, and the clufters of infects attached to it, which being thereby feparated, fall upon cloths previoufly

fpread

ſpread on the ground to receive them, and a ſufficient quantity being thus collected, they are dipped (incloſed in a linen cloth or bag) into boiling water, and ſuffered to remain in it ſo long as is neceſſary for killing them, but no longer, leaſt the water ſhould extract ſome of their colour. This being done, they are thoroughly dried by ſpreading and expoſing them to the rays of the ſun, by which they ſhrink ſo as generally to loſe about two-thirds of their former weight. This, which has been found to be the beſt method of drying the cochineal, is now generally practiſed, though others were formerly in uſe; ſuch as ovens, flat baking ſtones heated, &c.

Mr. Thiery de Menonville deſcribes the male of the domeſticated or fine cochineal as perfectly ſimilar to that of the wild in every reſpect, excepting its ſize; nor does there appear to be any conſiderable difference between the females of theſe two varieties. The domeſticated female, inſtead of that downy covering which enables the wild to bear inclement ſeaſons, is only covered by a fine white powder or farina, ſerving in ſome degree as a defence againſt rain and cold, but not enough to enable her to remain abroad like the wild inſects during the rainy ſeaſons, which occur twice in every year. When theſe approach, the domeſticated inſects are all gathered, excepting only thoſe intended for breeding a future ſtock, and theſe are preſerved by removing the nopals on which they are placed into ſituations where they are ſecured from wind and rain, or by raiſing frames over them, and covering them with thatch or matting, until the

the return of favourable weather; whereas the wild insects, being more hardy, as well as more prolific, when once placed upon the nopals, would not only perpetuate, but multiply themselves without any farther care to such a degree, as to exhaust and destroy the plants, were they not all collected at the end of every two months, and the nopals perfectly cleansed (by wiping them with wetted cloths) from the down and other animal impurities left on their branches. The nopals become fit to nourish the cochineal at the end of eighteen months from the time they were planted. The quantity of fine or domesticated cochineal which a single nopal can nourish, usually weighs a third more than it could nourish of the wild. These last have also the disadvantage of selling for a much less price, but in return they are gathered six times in each year, whilst the fine yield but three crops in the same space, their propagation being wholly suspended during the rainy seasons.

In Mexico it is thought necessary to keep the two sorts or varieties of cochineal separated, at the distance of about one hundred perches from each other, lest the males of the wild, impregnating the females of the other sort, should occasion a degeneration thereof; a circumstance which seems to indicate that both sorts originated from the same stock, and that the domesticated is only an amelioration of the wild cochineal, through the favourable effects of a more suitable nourishment, and of warm covering; and this is rendered the more probable, by Mr. Thiery de Menonville's observation, that the former are never found in the fields or forests of

Mexico, nor indeed any where, but in the gardens and plantations of thoſe employed in rearing them. But if the preſent ſize, appearance, and habits, of the domeſtic cochineal, were thoſe which naturally belong to the inſect, it might be ſuppoſed capable of maintaining an independent exiſtence, remote from the dwellings, and without the help of mankind, as it muſt have done before its properties were ſo well known, as to render it an object of human care and protection; and in that caſe, ſome of this ſort of cochineal doubtleſs would have continued to ſubſiſt in their natural ſtate, ſince the whole of a race, compoſed of ſo many minute individuals, could not have been taken and brought under the protection and dominion of man. Nor is it eaſy to explain why none of them ever are found in a wild ſtate, but by ſuppoſing them to have been rendered effeminate by luxurious food, and by protection from inclement weather; and that conſequently they have been enabled to lay aſide their natural downy cloathing, as ſheep lay aſide their wool, when, after being removed to warm climates, they find it no longer neceſſary; and that their natural habits and means of ſelf-preſervation being loſt, they are rendered incapable of ſubſiſting without a continuance of the ſame foſtering care which firſt occaſioned their effeminacy; or if they ever do find means to ſubſiſt without it, they do ſo only by regaining their natural downy covering, and by returning again to their primitive habits, ſo as not to be any longer diſtinguiſhable from thoſe who were never out of the wild ſtate.

After

After the death of Mr. Thiery de Menonville, the ſtock of fine or domeſticated cochineal, which he had multiplied in the garden at Port au Prince, was ſuffered to periſh by neglect; but the hardier wild ſort, having found means to ſubſiſt, though neglected, was afterwards taken under the care of Mr. Bruley, (ſubſtitute of the attorney-general of that province,) who, from the remains of Mr. de Menonville's eſtabliſhment, formed a plantation for propagating and multiplying theſe inſects, of which he ſent a conſiderable quantity, in the year 1787, to the miniſter of the French marine at Paris, at whoſe requeſt the Royal Academy of Sciences commiſſioned Mr. Berthollet, and three others of its members, to cauſe proper experiments to be made therewith, which they accordingly did, under their own inſpection, at the celebrated eſtabliſhment (for ſcarlet dying) of the Gobelines near Paris; and from theſe experiments it appeared, that the grana ſylveſtra of St. Domingo afforded colours by dying exactly ſimilar to thoſe of the Spaniſh fine cochineal, allowing only after the rate of twelve ounces of the former for five of the latter. Mr. Bruley ſome time after ſent to France a ſecond parcel of the ſame cochineal, produced from his plantation in the year 1788; and this being tried by the ſame commiſſaries of the Royal Academy, though in different ways, produced nearly the ſame effects.

Very conſiderable differences of external colour or appearance occur in different parcels of the fine cochineal; probably becauſe the white farina-

farinaceous powder, with which theſe inſects are naturally covered, is more or leſs waſhed off by the hot water in which they are killed by immerſion, as well as by other circumſtances which occur in the drying and packing. When this powder has been intirely removed, the inſects appear of a chocolate colour, inclining a little to the purple, and are then called *renigrida*. Generally, however, ſo much of the white powder remains, eſpecially in the little furrows which croſs the inſect's back, as occaſions a grayiſh appearance, called jaſpeada; and ſometimes indeed this powder ſo perfectly covers the cochineal, as to render them all over white. This I remember to have been particularly the caſe of a parcel which a friend of mine had purchaſed, and which was refuſed by ſeveral dyers to whom it had been ſent, from a perſuaſion of its having been fraudulently covered by white lead, or ſome other metallic calx intermixed with it, to increaſe the weight; and one very eminent dyer alleged, that he had formerly ſeen and tried a ſimilar parcel, and that the white powder had been found to conſiſt principally of a preparation of mercury. That I might be enabled to aſcertain whether an opinion ſo unlikely had any foundation, my friend cauſed ſeveral ounces of this powder to be ſeparated from the inſects by ſifting; and having tried it ſufficiently, I found it to be intirely of an animal nature, and apparently nothing but the farina which naturally covers theſe inſects. It even yielded a conſiderable portion of the true cochineal colour, and dyed good ſcarlets in the uſual way, though it probably was aſſiſted by ſome of the limbs or other parts of the bodies of the inſects, ſeparated

rated by rubbing in the ſieve: though I am perſuaded that a part of the colour in queſtion naturally exiſted in the farina or white powder itſelf; and if this be the caſe, it would be highly advantageous to contrive means for killing the cochineal, without waſhing off any part of the powder in queſtion, which might, I think, be done by putting them into tinned veſſels, made ſo as to ſhut cloſely, which might be plunged into boiling water, and withdrawn at a proper time, without letting a ſingle drop of it come into contact with the inſects, or carrying off any of the powder in queſtion. And perhaps this method might be uſed with advantage, even if it ſhould be found that no colouring matter reſides in the white powder, ſince it is difficult to conceive that the cochineal can be plunged into boiling water, ſo as to waſh away the powder intirely, (as is frequently done,) without a loſs of ſome part of the colouring matter contained in the bodies of the inſects themſelves.

The true original grana ſylveſtra ſeem to have been very different from what is at preſent ſold under that denomination in this kingdom, and which has the appearance of a dry powder, with many ſmall lumps or fragments of ſomething which had been previouſly formed into a cake or a dried uniform maſs. It affords indeed nearly the ſame ſpecies of colour as cochineal, but in a much ſmaller proportion; ſix pounds being neceſſary, according to my experiments, to dye as much cloth as one pound of the fine cochineal; whereas the true grana ſylveſtra are repreſented as yielding at leaſt half as much as the fine, and they ſell for at leaſt half the

price

price in ſome parts of Europe; whilſt here the ſubſtance ſo called, and which has not the leaſt appearance of any inſect, ſells at preſent for leſs than an eighth of the price of fine cochineal. Probably it is compoſed of the white downy ſubſtance which the wild inſects are repreſented as leaving in great abundance on the nopals, and of other excrementitious matters depoſited by them, joined to fragments, broken limbs, duſt, &c. of the inſects themſelves, and perhaps with an addition of ſome vegetable matters, all beat up into one uniform maſs. Something of this ſort was formerly practiſed even with the true cochineal, according to Dr. Brown, who ſays, "the cochineal inſects uſed to be prepared by "pounding them, and ſteeping the pulp in the "decoction of the texuatla, (a ſpecies of me-"laſtoma, as he ſuppoſes,) or that of ſome "other plants, which they obſerved to heighten "the colour. This, continues Dr. Brown, was "left to ſettle at leiſure, and afterwards made "into cakes and dried for the market." Probably the true grana ſylveſtra are what are ſold in this country under the name of Granillo, which appears, as the name indeed imports, to conſiſt of inſects ſomewhat ſmaller than thoſe compoſing the fine cochineal, and therefore in that reſpect anſwers to the beſt authenticated deſcriptions of the wild cochineal.

It had been generally believed that the cochineal derived its colour from the red or crimſon fruit of the nopals, and other ſpecies of opuntiæ; and I was formerly induced by this opinion to make various trials with the fruit of the cactus opunctia for dying, inſtead of cochi-

neal,

neal. They all indeed proved unfuccefsful; and I attributed this want of fuccefs to their want of that kind of animalization, which the vegetable red colour was fuppofed to receive when eaten and aflimilated by the infect; and I thought it probable, as indeed others have done, that many vegetable colouring matters might be equally improved in the fame way, and that perhaps, inftead of infects, it might be advantageous to employ large animals for this purpofe *. It is, however, now certain, from the obfervations of Mr. Thiery de Menonville, and from other well-attefted relations, that the cochineal infects do not feed on the red fruit of the cactus, but upon its branches or articulations to which they adhere, and which contain nothing like a red juice; and that they fometimes live, propagate, and preferve their colour on thofe fpecies of cactus which do not bear red-coloured fruits:

* Dr. Garden relates, that a negro woman in South Carolina, who then gave fuck, having eaten fix of the red fruit of the prickly pear, (Cactus Opuntia,) and fome of her milk being collected and left until the cream had feparated, this laft was found to be of a reddifh colour, confiderably weaker indeed than the lively red which the urine was found to acquire by the fame fruit. He found alfo, that after cows had been feeding in an indigo field, not only their urine, but the cream of their milk, " was of a moft beau-" tiful blue colour;" from whence he concludes, that the indigo blue colour refides in the oily part of the plant. See Philofoph. Tranf. vol. 50. p. 269.—And in the third vol. of the fame Tranfactions, mention is made of a berry growing in Bermudas, and called the " Summer Ifland Red-weed, " which berry is as red as the prickly pear, and giving " much the like tincture; out of which berry cometh out " firft worms, which afterwards turn into flies, (fomewhat " bigger than the cochineal fly,) feeding on the fame " berry, in which there hath been found a colour no whit " inferior to the cochineal fly."

confeconsequently the colour of these insects does not result from that of their food, but from their particular constitution and properties.

The very great demand for cochineal, almost immediately after it had been made known in Europe, caused a very rapid multiplication of it in the Spanish American settlements. It appears from Acosta's statement, that so early as the year 1587, there came to Spain, by a single flota, no less than 5670 arobas of fine cochineal, which, at the rate of 25lb. each, weighed 141,750 pounds; and the common annual importation, as stated some years since by the Abbé Raynal, amounted to 4000 quintals, or 400,000lb. weight of the fine cochineal, 300 quintals of the grana sylvestra, 200 ditto of granillo, and 100 of cochineal dust, which were computed to have sold for a sum equivalent to about nine millions of French livres; without reckoning considerable quantities sent directly from America to the Philippine islands, for supplying a considerable part of Asia. The European importations have, however, been considerably increased, during several of the last years. Since, according to very good information, which I have received, the quantities of fine cochineal brought to Spain in the years 1788, 1789, and 1790, amounted to eleven thousand bags, weighing 200lb. each, and making together 2,200,000lb. weight; and between the 1st of January 1791, and the 1st of October in the same year, the importations had exceeded 2000 bags.

It muſt, however, be obſerved, that the importations during theſe years were ſomewhat greater than uſual, becauſe an advance in the price of cochineal in Europe had induced the holders of it in America to ſend their ſtocks more ſpeedily to market, in order to avail themſelves of the higher prices; and, from accurate calculations, I think it may be concluded, that the average quantity of fine cochineal annually conſumed in Europe amounts to about three thouſand bags, or 600,000lb. weight, of which about 1200 bags, or 240,000lb. weight, may be conſidered as the preſent annual conſumption of Great Britain. A greater quantity comes indeed into the kingdom, but the ſurplus is again exported to other countries. Theſe 1200 bags may be ſuppoſed to coſt 180,000l. ſterling, valued at 15s. per lb. which has been about the average price for ſome years paſt. According to Don Antonio Ulloa, the greateſt quantities of cochineal are produced at Oaxaca, Tlaſcala, Chulula, Neuva Gallicia, and Chiapa, in New Spain, and at Hambatio, Loja, and Tucuman, in Peru.

About ſix years ago Dr. James Anderſon, phyſician-general on the company's eſtabliſhment at Madras, perſuaded himſelf that he had found the true cochineal inſects ſubſiſting naturally on a ſpecies of ſalt graſs in that part of India; and ſome parcels of a dried inſect, probably of the coccus kind, (but more like the kermes,) which he miſtook for the true coccus cacti, were ſent by him to this country; of which I made ſeveral trials, at the requeſt of a friend, (as others alſo did,)

did,) and found them to be neither of the ſame ſpecies, nor poſſeſſed in any degree of that particular colouring matter for which the cochineal inſect is ſo highly valued; though in their dried ſtate they had nearly the ſame external appearance, excepting their ſize, which was conſiderably leſs than that of the true Mexican cochineal; but upon rubbing them in a mortar, I ſoon perceived, that inſtead of breaking into a dry powder like cochineal, they could only be beat into a kind of unctuous paſte; nor would any degree of drying, ſhort of combuſtion, overcome this unctuous quality, or render them capable of being rubbed into the form of a powder; and in point of colour there was a more eſſential difference, ſince they produced nothing better than a chocolate brown, by the means uſually employed for dying ſcarlet with cochineal, nor indeed by any other means. This chocolate colour proved indeed ſufficiently durable on wool, but it may be dyed ſo cheaply by other matters, and indeed theſe inſects yielded ſo little of it, that they never can be worth collecting as a dying drug *.

It occurred to me, however, on this occaſion, that though Dr. Anderſon had failed in his expectation of finding the cochineal in a country

* The Company, in their letter of the 31ſt of July 1787, to the government of Madras, were pleaſed, from very laudable motives, to direct, that every further purſuit reſpecting this ſpecies of inſects "ſhould be effectually diſcourag-"ed," becauſe "were it to fall into the hands of improper "perſons, it might be made uſe of to mix with and adul-"terate the real cochineal, to the great injury of the con-"ſumer, as it would moſt aſſuredly ſpoil the beauty of every "ſcarlet done therewith."

 where

where it probably never exifted, (the genus of plants on which it is alone fitted and deftined to live having been originally produced only in America,) yet it would not be very difficult to convey both the infects, and the cactus cochenillifer (their natural food and habitation) to the Eaft Indies, and there propagate both, fo as in a few years to obtain from thence ample fupplies of a drug fo highly important in a great manufacturing country, and for which nearly 200,000l. fterling are annually paid by this to the Spanifh nation, efpecially as great advantages in this refpect would refult from the cheapnefs of labour and fubfiftence in the Eaft Indies; and confidering moreover how much the quality of the indigo of that country had been improved, and the quantity increafed within a few years, through the meafures taken fo opportunely for thefe purpofes by the Eaft-India Company, at a time when the ufual fupplies of that article from other countries had been greatly diminifhed.

Similar ideas on this fubject occurred, or were fuggefted, to the Directors of the Eaft-India Company, who in the fpring of the year 1788 procured from his majefty's botanic garden at Kew (through Sir J. Banks, Bart. P. R. S.), fome of the true nopal plants, two of which were fent out by the Bridgwater, during that feafon, to Madras, and put under the care of Dr. Anderfon, where they have fince been multiplied to feveral thoufands, and been tranfplanted from thence to Bengal and St. Helena, in order that a fufficient ftock might be in readinefs to receive any cochineal infects which

fhould

ſhould arrive; a committee of the Directors having previouſly reported as "their opinion, "that it be recommended to the Committee of "Correſpondence to take ſuch meaſures as they "they ſhall judge beſt ſuited for procuring "from America a quantity of the cochineal "inſect, with a view to the introduction of the "ſame upon the coaſt of Coromandel." Unfortunately, however, it does not appear that any meaſures have yet been effectual in procuring the domeſticated inſect, or even the ſylveſtra, though this laſt exiſts in Jamaica, (as does the true nopal,) and in many other acceſſible parts of America, and probably in more than ordinary perfection in Brazil; at leaſt I made trial about the year 1787 of ſome which had been ſent from thence by the way of Liſbon, and which yielded *full* as much colour, and of as much beauty, as half its weight of the *very beſt fine cochineal*; and until this laſt can be obtained, would it not be adviſable to make trial of the other, which, by being properly nurſed, and nouriſhed upon the true nopals, might perhaps in a little time improve ſo as to ſuperſede the neceſſity of ſeeking any farther?

## CHAP. XI.

*Of the Properties and Uses of Cochineal; with an Account of new Observations and Experiments calculated to improve the Scarlet Dye.*

"Le travail a été mien, le profit en soit au lecteur."
JEAN REY.

IN the English translation of Clavigero's History of Mexico, the ancient inhabitants of that country are said to have obtained a *purple* colour from cochineal. Probably, however, either the author or translator of that work has mistaken purple for crimson; this last being the *natural* colour of cochineal, and what it always affords with the aluminous basis, which Clavigero, in another part of his history, says, the Mexicans had been used to employ in early times; though it certainly is difficult to understand how they could have become acquainted with it. This account moreover accords with that of Herrara, who, after mentioning the Tuna or Nopal of Tlaxcalla, says, "Optimum "longè granum dat Tlaxcallum cujus indigenæ "prestantissimam tincturam ex illo conficiunt, "hoc modo, comminuunt & macerant in de-"cocto *aluminis*, & ubi resederit, cogunt in ta-"bellas, quas Hispani vocant *grana en pan*."

There is also reason to conclude, that during a number of years none but the aluminous basis was used for dying with cochineal in Europe, until

until an opportunity had been accidentally afforded to Kuſter, Kuffler, or Kepfler, a German chymiſt, of ſeeing the wonderful effects of a ſolution of tin, by nitric acid, in exalting the colour of this drug, which led to a diſcovery of that moſt vivid of colours, the cochineal ſcarlet. Kuſter brought his ſecret to London about the year 1543, and the firſt eſtabliſhment for carrying it into practice ſeems to have been made at Bow, from whence ſcarlet was called the Bow dye in this country. Some writers, and among them Mr. Macquer, have aſcribed this diſcovery to *Drebel*, a Dutch chymiſt *; but Kunckel, and others, who have attributed it to Kuſter, appear to have done it on better grounds. Probably Drebel obtained a knowledge of it very

* Mr. Macquer, in a Memoire, printed among thoſe of the Academy of Sciences of Paris for 1768, ſays, " Drebel, chimiſte Hollandois, a imaginé d'employer dans la " teinture de cochenille, de la diſſolution d'etain faite par " l'eau regale, & des lors on a obtenu le plus vif & le plus " celatant de tous les rouges dont l'art, & meme la nature " nous ait donné l'idée; je veux dire l'ecarlate couleur de " feu, qui a porté d'abord le nom *d'ecarlate de Hollande*, " parceque c'eſt dans ce pays que les premieres manufac" tures ont été etablies," &c.

Mr. Macquer ſeems alſo miſtaken in ſuppoſing that the firſt ſolutions of tin employed in this way were nitro-muriatic, or made with aqua regia, there being very good reaſon to believe, that aqua-fortis alone was uſed for ſome years for this purpoſe.

Mr. Delaval inclines to carry the firſt uſe of tin for dying, back to very remote antiquity; and thinks the Phenicians uſed that which they were ſaid to have brought from Britain in this way, becauſe (as he erroneouſly aſſerts) " this is " neceſſary to the production of red colours, whether from " animal or vegetable materials." See Experimental Enquiry, &c.

ſoon after the diſcovery was made, and that in conſequence thereof ſcarlet dying was very early practiſed in Holland; as it was alſo in France, by the famous Gobelins, who received an account of the proceſs from Kloeck, a Flemiſh painter, to whom it had been communicated by Kuſter himſelf. As the name of ſcarlet had, until that time, been invariably given to the fine reds dyed with kermes, the *fiery* cochineal colour, which in England was diſtinguiſhed as the Bow dye, obtained in other parts of Europe the name of Dutch Scarlet, Scarlet of the Gobelins, &c.

It has been generally ſuppoſed, that after the effects of tin upon the cochineal colour had been diſcovered, as before mentioned, nothing more was wanting to produce what is at preſent called ſcarlet, than to apply the colour ſo produced as a dye to wool; or, in other words, that a nitric, or nitro-muriatic ſolution of tin, was ſufficient to change the natural crimſon of cochineal to a ſcarlet. Such at leaſt has been the opinion of every writer on the ſubject until the preſent hour; though it will hereafter be proved to have been an erroneous opinion, and that the nitric ſolution of tin invariably produces (with cochineal) a crimſon or roſe colour, and not a ſcarlet, unleſs other means be alſo employed to incline the cochineal colour ſo far as may be neceſſary towards the yellow hue; and the means of doing this ſeem to have been ſtumbled upon, and continually employed without any knowledge of their true effect. I have already mentioned that tartar is, and for many ages appears to have been, generally employed with alum,

alum, to compoſe the ordinary boiling liquor or mordant for woollen cloths; and it ſeems probable, that when the firſt attempts were made to employ the ſolution of tin, inſtead of alum, it would naturally have been imagined, that as tartar had been found uſeful with the latter, it muſt alſo produce good effects with the former, and that a trial of it having been thus produced, and the moſt brilliant of all colours having been found to reſult from this combination of tartar with the ſolution of tin, their joint uſe was afterwards continued, without any inquiry concerning the particular ſhare which either of them had in producing ſuch pleaſing effects.

At firſt indeed a diluted nitric acid appears to have been employed for diſſolving the tin without any admixture of the muriatic; but as the former would have held but a ſmall portion of the calx of that metal in a ſtate of ſuſpenſion, and as even that portion would have been liable to precipitate in a few days, the practice of adding either a little ſal-ammoniac, or a little ſea ſalt, to the aqua-fortis, and of thereby producing an aqua regia, or nitro-muriatic acid, ſeems to have been introduced, though it did not become general until a conſiderable time after; ſince Hellot gives an account of the proceſs uſed in his time for dying ſcarlet at Carcaſſonne, in which tin was diſſolved *only* by diluted aqua-fortis; and he mentions the late Mr. Baron, as claiming the merit of having been the firſt in that city who employed an aqua regia for diſſolving tin, *in order to prevent a precipitation of its calx or oxide*; and even when this was done, the ſal ammoniac and ſea ſalt were added but

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very ſparingly, from a belief, which ſtill ſubſiſts univerſally, that a more liberal uſe of either of them in this way, or of the muriatic acid in their ſtead, would render the cochineal colour a crimſon inſtead of the ſcarlet, which laſt is ſuppoſed to be a peculiar production of the nitrate of tin; though nothing can be more groundleſs than this belief; ſince the nitrate, and the muriate of tin, both *equally* afford a crimſon colour with cochineal, and neither affords a ſcarlet without the aid of other means.

The dyers' ordinary ſolution of tin is made with that ſpecies of nitric acid, called ſingle aqua-fortis, and which, as uſually prepared, is capable of diſſolving about one-eighth of its weight of tin, grained or granulated, by pouring it, when melted, into water, briſkly agitated with a bundle of rods, or by other ſuitable means.

For each pound of aqua-fortis, it is uſual to add after the rate of from one to two ounces of ſea ſalt, though ſome prefer the muriate of ammoniac (ſal ammoniac) for this purpoſe. A little water is moreover commonly added, in order ſtill farther to dilute the acid, and moderate its action on the tin. Thoſe ſolutions of it which were made moſt ſlowly, and with the leaſt ſeparation of fumes or vapours, have been found to ſucceed the beſt; probably becauſe in theſe the tin is leſs calcined, and the ſolution retains a larger portion of azote than in thoſe which proceed more rapidly. It is uſual to allot after the rate of two ounces of grained tin to every pound of aqua-fortis; and the me-

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tal ſhould be put into it at different times, waiting until one part is nearly diſſolved, before another is added, leſt too much heat ſhould be evolved, and the ſolution proceed too rapidly; though there is no danger of this, in the latter part of the proceſs, which indeed ſhould be protracted ſo as to laſt two or three days. The water mixed with the aqua-fortis ſhould be aſcertained by weighing or meaſuring, in order that a proper allowance may be made for it in calculating the ſtrength of the ſolution, or the weight of metal contained in a given quantity thereof, which, ſuppoſing half as much water as of aqua fortis to have been uſed, will be about one-thirteenth part of the whole; and when the ſolution (which the dyers in this country generally call *ſpirit)* has been made in theſe proportions, about eighteen or twenty pounds of it will be wanted to dye a full cochineal ſcarlet, upon one hundred pounds weight of woollen cloth, though but little more than half of this quantity is uſually employed in the firſt preparation, or boiling part of the proceſs; for which, ſuppoſing one hundred pounds weight of cloth are intended to be died, eight or ten pounds of tartar or argol are put into a ſuitable dying veſſel, (of pure block tin,) with a ſufficient quantity of clean ſoft water *, and ſix or eight ounces of powdered cochineal. Immediately after this, ten or twelve pounds of the ſolution of tin, prepared as before mentioned, are to be added; and when the mixture is nearly ready to boil,

* Hard water tends to produce a roſe colour, which the dyers commonly endeavour to obviate, by boiling bran or ſtarch in their water.

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the cloth being firſt thoroughly moiſtened, (that the dye may penetrate and apply itſelf equally thereto,) is put into the dying liquor, and turned through it (by the winch) a few times very quickly at firſt, and afterwards more ſlowly, whilſt the liquor continues to boil, for the ſpace of an hour and a half or more, after which it is to be taken out, and rinced in clean water. By this *firſt boiling* or preparation, the cloth will have acquired a fleſh colour. For the *ſecond*, or dying proceſs, the tin veſſel is repleniſhed with clean water, and when this appears almoſt ready to boil, five, or if a *full* colour be wanted, ſix pounds of cochineal in powder are to be put into it, and well mixed, by ſtirring for a few minutes; after which, the remaining part of the ſolution of tin is to be added, and the whole being well ſtirred, the cloth is to be put into the liquor, and turned *very briſkly* through it, over the winch, for a little time, in order that both ends may receive an equal portion of the dye; after which it may be turned more ſlowly for the ſpace of half an hour, or until the dying liquor becomes exhauſted, when the cloth is to be taken out, aired, and rinced.

An ounce of fine cochineal is generally deemed neceſſary for dying a pound of cloth; but ſomething leſs than this portion is frequently made to anſwer, eſpecially for coarſer cloths.

It is by no means neceſſary to follow this (which is the uſual) proceſs for dying ſcarlet. I have often given that colour very well at one ſingle boiling, (without any preparation,) by mixing

mixing the whole quantity of tartar, ſolution of tin, and cochineal together; for ſuch, in this caſe, is the attraction of wool for the colouring matter, as well as for the oxide of tin, that it will take up both very freely, and retain them permanently when thus mixed. I think, however, that in this way the cloth does not exhauſt the colour of the dying liquor quite ſo perfectly as in the other; which ſeems alſo to be the caſe, where, inſtead of emptying out the boiling liquor after the firſt preparation, the remainder of the ſolution of tin and the cochineal are added to it, and the cloth is dyed therein; and as far as I can judge, there is no other reaſon for incurring ſo much expence of fuel, labour, and time, than this, which indeed is not a ſufficient reaſon, where there are other cloths to be dyed of ſimilar colours immediately afterwards; becauſe what may have been left by the firſt, will naturally be gained by thoſe which are afterwards dyed in the ſame veſſel.

I have moreover often dyed very beautiful ſcarlets, by preparing or boiling the cloth with the *whole* quantity of ſolution of tin and tartar at once, (as is commonly done with alum and tartar,) and afterwards dying it unrinced with the whole of the cochineal in clean water only; and in this way I have found the colouring particles ſo completely taken up by the cloth, that the liquor became as clear as the pureſt water, and the colour was generally very perfect.

Some dyers, beſides the tartar uſed in the firſt boiling, employ as much of it as of cochineal in the ſecond or dying part of the proceſs; and certainly

certainly the doing ſo will be advantageous, whenever the colour is wanted to approach nearer than ordinary to the aurora complection, though this is not the effect which would be generally expected to reſult from thence. Pœrner uſes no cochineal in the firſt boiling, nor indeed is any neceſſary, though a little may probably help to decompoſe the oxide of tin, and fix it more copiouſly in the fibres of the cloth. For ſcarlet, many dyers prefer the red argol or crudered tartar; but the matter to which it owes this colour is wholly incapable of adding any colour to that which the wool may otherways acquire, and therefore at beſt it will only prove uſeleſs. Wool is ſeldom dyed ſcarlet until it has been ſpun, wove, and fulled; becauſe the yellowiſh tendency which the cochineal colour acquires from tartar in the dying proceſs, is nearly all taken away in the fulling, and a *roſe* produced inſtead of a ſcarlet colour.

Mr. Berthollet thinks the ſolution of tin, before deſcribed, does not affect the cochineal colours, *merely* by the proportion of that metal, which it contains; and that when either ſal ammoniac, ſalt-petre, or common ſalt, enter the compoſition of an aqua regia, the compound will be leſs acid than when it conſiſts of the nitric and muriatic acids ſolely; and that the former deſerves therefore to be preferred, as having a leſs violent action upon the fibres of woollen cloths, and upon colouring matters.

It is remarkable, that during the preſent century, no conſiderable improvement has been made in the proceſs or means of dying ſcarlet; a cira circumſtance which is the more extraordinary, ſince the pre-eminent luſtre, as well as the coſtly nature of this dye, have rendered it an object of particular attention, not only to dyers, but to eminent chymiſts, by whoſe reſearches we might have expected, that at leaſt every obvious improvement therein would have been long ſince attained. That this, however, has not been done, will, I think, manifeſtly appear, by the following ſtatement of my own particular obſervations and experiments on this ſubject, which began in the year 1786. Having been led to pour boiling water repeatedly upon powdered cochineal in a china baſon, and to decant it as often from the ſubſiding inſoluble parts, until they would yield no more colour, I found that by adding a little pot-aſh to this ſeemingly exhauſted ſediment, and pouring freſh boiling water thereon, a farther copious extraction of colour inſtantly diſplayed itſelf, equal, as far as I could judge, to about one-eighth of the whole of that which had been originally contained in the powdered inſects; and having by repeated trials conſtantly found this effect, I too haſtily concluded that the colour thus obtained by the help of pot-aſh was ſo far of a reſinous nature, or ſo intermixed with a reſinous matter, as to have always been incapable of being extracted by the means uſually employed for dying with cochineal; and that if it ſhould be found capable of yielding colours as beautiful and permanent as thoſe dyed with the more ſoluble colouring particles of theſe inſects, an acquiſition might be made of ſo much *new* colouring matter, which till then had, as I conceived, been always thrown away. That it was capable of yielding ſuch colours, I ſoon aſcertained, by repeatedly extracting this particular colouring matter by the help of pot-aſh, and afterwards dying ſmall pieces of cloth ſcarlet with it, (in the ways uſually employed for dying that colour,) and by comparing and expoſing them to the weather with other pieces dyed from the more ſoluble colouring matter of cochineal.

Continuing my inquiries on this ſubject, I ſoon perceived that the colour, denominated ſcarlet, muſt in fact be a compound colour, (like green, purple, and orange,) conſiſting probably of about three-fourths of a moſt lively pure crimſon or roſe colour, and about one-fourth of a pure bright yellow; and that therefore when the natural crimſon of the cochineal is made ſcarlet by the means always hitherto employed for dying that colour, there muſt be a *change* produced equivalent to a converſion of one-fourth of the cochineal colouring matter from its natural crimſon to the yellow colour; and as a better yellow might be obtained from other drugs, where it naturally exiſts, and for a fiftieth part of what it coſts when obtained in this way, from the *moſt coſtly of all dying drugs*, (cochineal,) it neceſſarily followed, that this, the univerſal and only known method of producing a ſcarlet, muſt be highly injudicious, becauſe unneceſſarily expenſive.

Convinced of this important truth, and at the ſame time believing too eaſily, on the authority of Hellot, Macquer, and others, that the natural

tural crimſon of cochineal was rendered ſcarlet only by the nitric acid employed to diſſolve the tin uſed in dying that colour, I began a ſeries of experiments for producing it, without any ſuch *waſte* of the cochineal colouring matter. For this purpoſe it ſeemed neceſſary to diſcover a mordant or baſis, capable of permanently fixing and ſtrongly reflecting the pure vivid cochineal crimſon, without giving it any tendency towards the yellowiſh hue. I concluded, and found by experiments, that the neceſſary *purity* and *vivacity* of colour could not be obtained from an aluminous baſis, however diſſolved, though it doubtleſs fixes the colouring particles of cochineal more durably than any other mordant; and the like defect was found to accompany the ſolutions of all the other earths, as well as of the metals and ſemi-metals, tin alone excepted; and with this farther diſadvantage, that moſt of them either degraded or altered the natural colour of cochineal very conſiderably. It followed therefore that a baſis to ſuit my purpoſe muſt be ſought for in the pure white calx of tin, ſo diſſolved or combined as to reflect the cochineal crimſon unchanged, and with the greateſt poſſible luſtre. Miſled by what thoſe eminent writers Dufay, Hellot, Macquer, Scheffer, le Pileur d'Apligny, &c. had advanced, as well as by the opinions of others, with whom I had converſed on this ſubject, I erroneouſly concluded, that all ſolutions of tin, in which the nitric acid predominated, would neceſſarily incline the cochineal crimſon towards the yellowiſh hue, and that therefore ſuch ſolutions ought to be excluded from my experiments. In this perſuaſion, I diſſolved parcels of that metal in almoſt every other acid, and tried them ſeparately for dying with cochineal. Their ſeveral effects will hereafter be more particularly ſtated: at preſent I need only mention, that of all others the muriatic ſolution ſeemed the beſt ſuited to anſwer my purpoſe, as it both fixed and reflected the pure crimſon or roſe colour of the cochineal unchanged, and with the utmoſt brightneſs. To produce a ſcarlet, therefore, it was only neceſſary to ſuperadd, and intimately combine with this crimſon or roſe colour, a ſuitable portion of a lively golden yellow, capable of being properly fixed and reflected by the ſame baſis. Such a yellow I had previouſly diſcovered in the *Quercitron* bark, (which will be the ſubject of my next chapter,) and alſo in what is here called young fuſtic, (Rhus Cotinus, Lin.) though its colour was much leſs bright, and much leſs durable, than that of the Quercitron bark; for ſamples of each, dyed by the ſame means, having been alike expoſed to the weather at the ſame time, the fuſtic colour was nearly deſtroyed, before that of the bark had ſenſibly faded. This laſt had alſo the advantage of being not only the brighteſt, but the cheapeſt of all yellows, ſince one pound of the bark in powder, which coſt but three-pence farthing, dyed, with a ſufficient quantity of muriate of tin, between thirty and forty pounds weight of woollen cloth of a full bright golden yellow; and this being afterwards dyed in the ſame liquor, with one-fourth leſs of cochineal than what is uſually employed, acquired a ſcarlet equal in beauty and durability to any which is ufually given by the ordinary means, with a full proportion of cochineal; and fuch were the general refults of a great number of experiments.

The quantity of muriatic folution of tin neceffary to dye a given quantity of fcarlet in this way, feemed to me at that time to depend on the proportion of metal contained in it, and this laft to depend on the ftrength of the acid ufed for that purpofe. That which I employed, and which I bought at the price of 38s. per 112lb. or about four-pence per pound, diffolved in a ftrong fand heat, one-third of its weight of granulated tin; and this folution would, with the proportions of cochineal and bark before mentioned, dye about ten times its weight of cloth, of a good fcarlet colour.

I have faid that three pounds of muriatic acid, which coft but one fhilling, might be made to diffolve a pound of tin, which would require eight pounds of fingle aqua-fortis to diffolve it; and this quantity of aqua-fortis, at the rate of 8d. per lb. would coft 5s. 4d., fo that on each pound of tin diffolved by muriatic acid, inftead of the nitric, I calculated a faving of 4s. 4d. The muriatic acid, therefore, which M. Beaumé had ftiled the true diffolvent of tin, ("Le vrai "diffolvant de l'Etain,") feemed alfo to be of all others the cheapeft; and with this farther advantage, that a folution made by it was as tranfparent and colourlefs as the pureft water, and capable of being preferved for many years, without the leaft alteration, whilft the dyers' nitro muriatic folution of tin or fpirit becomes turbid or gelatinous very ſpeedily, and even in a very few days, if the weather be warm.

I may add alſo, that the muriatic ſolution of tin ſeemed to exalt the colours both of the Quercitron bark and of cochineal, more than any other.

I perceived moreover another advantage reſulting from this new method of dying ſcarlet, by a ſaving of all the tartar employed in the old. Before I began my experiments on this ſubject, I had endeavoured to learn the purpoſe which tartar was intended to anſwer in the uſual proceſs for dying ſcarlet; but having obtained no ſatisfactory anſwer on this point, I doubted of its producing any good effect, and therefore omitted it in my firſt trials; and as they ſucceeded, I alſo omitted it in all the others.

By theſe facts and ideas, I was led to believe that I had made diſcoveries likely to produce very important national benefits; and I particularly calculated in the firſt inſtance a gain of about 12 ½ per cent. upon the whole quantity of cochineal conſumed in Great Britain, by that part of its colouring matter which I propoſed to extract by the help of pot-aſh, and which I ſuppoſed to have been before always loſt.

Beſides this, I computed that a ſaving of 25 per cent. upon all the cochineal uſed in Great Britain for dying ſcarlet, aurora, and orange colours, would reſult from my plan of obtaining from the Quercitron bark ſo much yellow as was required for the compoſition of thoſe co-

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lours with the cochineal crimſon, inſtead of converting any part of this laſt more coſtly colour into a yellow. And laſtly, I calculated other ſavings, equal at leaſt to 20,000l. annually, in the article of tartar, and in what the muriatic ſolution of tin was likely to coſt leſs than that which is commonly uſed for the purpoſes in queſtion.

With this opinion of the importance of my diſcoveries on this ſubject, I gave an account of them, as well as of an improvement in the black dye, (which will be hereafter explained,) to the Right Honourable the Lords of the Committee of his Majeſty's Privy Council, appointed for the conſideration of all matters of trade, &c. and their lordſhips, with a laudable ſolicitude for the public welfare, were pleaſed, by an order bearing date at Whitehall, the 18th of September 1787, to refer the ſame to "ſix capital "dyers," named in the ſaid order, who were "deſired to inquire into the facts reſpecting the "ſaid important diſcoveries in the black and "ſcarlet dyes;" and afterwards "to report to "the committee their opinion of the merits and "utility" thereof.

It was not, however, until the 22d of January following that an experiment relating to the ſcarlet dye was made at the dye-houſe of Meſſrs. Goodwin, Platt, and Co. Bankſide, Southwark.—Conſidering on that occaſion how much practical operators, in all the arts, are inclined to diſtruſt improvements offered by ſpeculative men upon the grounds of theory or

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philoſophical reaſoning, I was deſirous of making my firſt trial, under the moſt favourable circumſtances, in order that by its ſignal ſucceſs I might effectually obviate the effect of any unfavourable prepoſſeſſions in the minds of thoſe who were to report on the merits of my diſcoveries. For this purpoſe I prepared a large quantity (near 100 lb.) of the muriatic ſolution of tin; and in order that the acid might be perfectly ſaturated with the metal, I added an over proportion of the latter, and kept both at the boiling point, by means of a ſand heat, for the ſpace of three days and nights. In this way I obtained a ſolution perfectly colourleſs, of a very pungent ſmell, and ſo highly volatile, that like æther it was almoſt impoſſible to prevent its eſcape from the veſſels in which it was contained, however cloſely ſtopped. The acid had in this inſtance diſſolved as much tin as it was capable of doing; but this complete ſaturation, inſtead of proving beneficial, as I had expected, became an obſtacle to my ſucceſs.

Two pieces of long baize, weighing together 188 lb. had been choſen as the objects of this experiment. I had before obſerved, in my private trials, that the colour generally proved moſt lively when given with a full proportion of the muriate of tin; and alſo that the colouring matter of the cochineal was moſt completely imbibed and *taken up* out of the dying liquor by the cloth, when the whole portion of the ſolution of tin, inſtead of being applied at different times, was boiled up at once with the Quercitron bark; an effect the more deſirable for me, be-

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cause I intended to employ a very small proportion of cochineal, and therefore wished to leave as little as possible of its colouring matter behind, floating in the dying liquor, especially as it would be difficult properly to estimate the exact quantity remaining therein.

For these reasons, I took a large portion of the solution of tin, *i.e.* 16lb. weight for the two pieces of baize, and threw the whole of it at once, with five pounds of powdered Quercitron bark, into a suitable tin vessel, properly filled with water a little warmed, into which the pieces of baize (previously moistened) were soon after put, and turned as usual over a winch through the liquor (which was made to boil) for the space of an hour, when they were both taken out, and rinced in clean water, the dying vessel being at the same time emptied, and then filled again with warm water for the remaining part of the operation. The baize had, in this first boiling, acquired a very bright golden yellow, though but about one-fortieth part of its weight of bark was employed; and I had expected, from what had before happened in my own particular experiments, that it would have been so fully impregnated by the metallic basis, as to want no farther addition of the muriate of tin in the second part of the process. To secure myself, however, against a disappointment on this point, I cut off a bit from one of the pieces, and boiling it in a small pipkin with water, and a little cochineal, I saw with great concern that the fibres of the cloth were very far from having imbibed enough of the calx of tin to fix and raise the cochineal colour; and that a farther portion of the ſolution would be abſolutely neceſſary for this purpoſe. My diſappointment in this reſpect appeared by ſubſequent experiments to have ariſen from my having puſhed the ſolution of tin (whilſt making it) on to that point of complete ſaturation at which the muriatic acid and the metal combine moſt cloſely, and are decompoſed with the greateſt difficulty, which had been manifeſtly the caſe in this inſtance; becauſe the water into which the ſolution of tin was poured in the dying veſſel did not decompoſe any part of it, or become in the ſlighteſt degree turbid, as it does with other ſolutions of that metal; and the attraction of the woollen cloth was much too feeble to ſeparate and attach to itſelf any part of the calx of tin, excepting only that which united with the colouring matter of the bark, and by this additional affinity became fixed in the wool as the baſis of that golden yellow which it had received, as already mentioned; whilſt the other and greater part of the calx remained in the water, (combined with the muriatic acid,) and was thrown away with it after the firſt boiling, but unfortunately not without having previouſly weakened the fibres of the wool by its corroſive property, of which I had then no ſuſpicion, though it became manifeſt in the ſecond part of the operation. For this, five pounds of cochineal were put into the dying veſſel, with ſix pounds more of the muriate of tin, and being well mixed in the water, the two pieces of baize were put into the liquor, and dyed therein for about fifteen minutes, when the colour not ſeeming to riſe properly, four pounds more of the ſolution of tin, and one pound of cochineal, were

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added; and the dying was continued, until it appeared ſoon after that the texture of the cloth was greatly injured by the muriate of tin, which ſeemed in this, as well as in ſubſequent trials, to have a much ſtronger and more corroſive action upon the fibres of wool than other ſolutions of that metal, though before that time I had always been perſuaded that it would on the contrary have acted more mildly in this reſpect than the ordinary dyers' ſolution or ſpirit; and indeed I had been led to this perſuaſion by the concurrent opinions of ſeveral very eminent chymiſts, who had all repreſented the nitric acid as exerting a ſtronger and more corroſive action than the muriatic upon animal ſubſtances. Even that moſt excellent chymiſt Berthollet has obſerved, in the tenth volume of the Ann. de Chymie, publiſhed ſo lately as the month of Auguſt 1791, and after he had been particularly employed in examining the effects of the different acids upon wool and ſilk, that "l'acide "ſulfurique & l'acide muriatique exercent une "action moins vive, ſur les ſubſtances animales "que l'acide nitrique ſuffizamment concentré." And this doubtleſs is true of theſe acids acting merely as acids; but very different properties appear to reſult from their combinations with metals, and metallic ſubſtances; among which, the metallic ſolutions by muriatic acid ſeem generally more corroſive than thoſe made by any other. This is particularly true of the muriates of mercury, ſilver, lead, biſmuth, and antimony, as well as that of tin; but the corroſive nature of this laſt, and the difficulty of decompoſing it, ſeem to be increaſed, in propor-
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tion as the muriatic acid is more completely ſaturated or combined with a greater portion of the metal. It is indeed true, that the proportion of ſolution of tin uſed in the foregoing experiment, was much greater than I had ever before employed, as it amounted to 26lb., and contained above ſix pounds of the metal, which is four times as much as would ſuffice (diſſolved by a mixture to be hereafter explained) for the ſame weight of cloth. But ſtill I am perſuaded, that an equal quantity of any other ſolution of tin would not have injured the like quantity of cloth in an equal degree; and being thus made ſenſible of the danger that muſt attend the uſe of a mordant ſo corroſive, I was convinced of the expediency of ſearching for one more harmleſs in this reſpect, though it certainly is very poſſible, with proper care, to employ the muriate of tin (containing a ſmaller proportion of the metal) ſo as to produce all the good effects which I had expected from it, without any injury to the cloth, as I have found by a multitude of experiments ſince, as well as before, that of the 22d of January 1787.

From whence this corroſive property of the muriate of tin ariſes, may become a ſubject of future inquiry. At preſent I ſhall only obſerve, that in ſome experiments which I made, with the hope of correcting it, I conſtantly found this ſaturated and highly corroſive muriate of tin poſſeſſing a ſtrong attraction for oxygene, and that by abſorbing it, as it did from various matters, this corroſive property was always greatly diminiſhed. This led me to oxygenate the

the muriatic ſolution of tin, by putting a little manganeſe into it, or rather by diſſolving tin with a little manganeſe in muriatic acid; but though the ſolution made in this way was evidently much leſs corroſive, it contained a ſmall portion of the manganeſe which darkened the cochineal colour, making it incline towards a purple; and this defect, though in a much leſs degree, accompanied the ſolution of tin made by the oxygenated muriatic acid, as prepared for bleaching.

I afterwards oxygenated the muriatic acid, by mixing it with about one-third leſs than its own weight of the nitric, and with this I made a ſolution of tin; which appearing to be no more corroſive than the common dyers' ſpirit, and not changing the cochineal crimſon towards the yellow hue, I was haſtily induced to venture with it upon another trial at the dyehouſe of Meſſrs. Goodwin and Co. a few weeks after the firſt. It was, however, made only on one piece of baize, weighing about ninety pounds, which I cauſed to be boiled with about eight pounds of this murio-nitric ſolution of tin, and two pounds and one-half of powdered Quercitron bark. This mordant, however, acted very feebly, or rather failed, in exalting the yellow colour of the bark, which took but very ſlowly on the baize, and never roſe much higher than a ſtraw colour, even after two hours boiling; when a conſiderable quantity of yellow colour, united to the calx of tin, evidently remained floating in the water, not becauſe the calx was too intimately combined with the acid ſolvent as in the firſt experiment, but becauſe,

for

for want of a ſufficient attraction between them, it had been almoſt wholly decompoſed as ſoon as they were put into water; and in boiling, it fixed itſelf with the bark colour upon the cloth but ſparingly and ſlowly. This alſo happened in the ſecond part of the operation; for which three pounds of cochineal, and ſix of this murio-nitric ſolution of tin, were at firſt employed; but the colour not riſing ſufficiently, another pound of cochineal, with four pounds more of the ſame ſolution, were added to the liquor in which the cloth was dyed for the ſpace of two hours, when a conſiderable part of the colour ſtill appeared floating, but not diſſolved, in the water. So much, however, had been applied to the cloth, as to give it a paſſable ſcarlet colour, which however had penetrated but very little into its ſubſtance, and ſeemed, as Mr. Goodwin obſerved, to have been rather painted than dyed. It was, however, generally agreed, after a particular examination, that notwithſtanding the great length of time in which the baize had been boiled with a very large proportion of the ſolution of tin, (*i. e.* 18 lb. for a ſingle piece weighing but 90 lb.), its texture had not received the ſmalleſt injury; ſo that in this reſpect my laſt experiment proved leſs expenſive than the firſt, though both together coſt me near 30l.

As this murio-nitrate of tin, though exempt from the defects of the muriatic ſolution, had failed through others of a very oppoſite nature, I was induced to mix much greater proportions of nitric with the muriatic acid for diſſolving tin, in order to ſee how much of the former could

could be uſed in this way, without ſo far yellowing the cochineal crimſon as to preclude the uſe of any of the Quercitron yellow in the dying of ſcarlet, an effect which I ſtill expected from the nitric acid, when uſed in a very large proportion; but to my great ſurprize, I could diſcover no ſuch effect, even when I had diſſolved the metal in nitric acid *alone*. At firſt I ſuſpected ſome impurity in the acid which had been employed; but having procured a freſh ſupply, and aſcertained its purity by the proper means, I ſtill found that tin diſſolved by it had not the leaſt tendency to change the cochineal crimſon towards a yellowiſh or ſcarlet hue; and that this effect, in the uſual way of dying that colour, reſulted wholly from the tartar, which is always employed at the ſame time. This fact I aſcertained by repeated and varied experiments, in which I conſtantly found that cochineal, with the dyers' common ſolution of tin, and even with that made by nitric acid only, would produce nothing but a crimſon without tartar; and that cochineal, with tartar, would produce a ſcarlet, not only with theſe laſt mentioned ſolutions, but alſo, *and equally well*, with the muriatic ſolution of that metal; and therefore, that every thing which had been taught and believed to the contrary was repugnant to truth. And here I cannot conceal my wonder, that an error of ſo much conſequence, and ſo deſtitute of all foundation, ſhould have been propagated and confirmed by ſo many acute reaſoners and ſagacious obſervers in other reſpects; for beſides thoſe eminent writers already mentioned, Mr. Pœrner has more recently adopted and

and propagated the ſame error, after making a great number of experiments, ſeveral of which, if they had been duly conſidered, would have taught him the truth on this ſubject*. This alſo was even more lately done by Mr. Berthollet, in his Elemens de l'Art de la Teinture, where, to adopt the words of Dr. Hamilton's Tranſlation, he ſays, "Tartar, as we have ſeen, "gives a *deeper* and *more roſy hue* to the co-"louring matter of cochineal, precipitated by "the ſolution of tin. It moderates the action "of the nitro-muriatic acid, which tends to "give ſcarlet an orange caſt, though this orange "caſt is not to be ſeen in the precipitate pro-"duced by the ſolution of tin, which is on the "contrary of a fine red. It is probable that "the ſolution of tin gives ſcarlet an orange "tinge, by means of the action the nitro-mu-"riatic acid exerts on the wool, which, as well "as all other animal ſubſtances, it has the pro-"perty of turning yellow."

"Thus (adds he), by putting more of tartar "into the reddening, a deeper and fuller ſcar-"let may be obtained; and on the contrary, "the ſcarlet may be rendered more inclining "to orange by omitting this ingredient." And he concludes the chapter by repeating this doctrine.

Here then it is manifeſt, that the nitro-muriate of tin and the tartar are each ſuppoſed to

* See Inſtruction ſur l'Art de la Teinture, &c. a Paris 1791.

produce

produce effects *directly contrary to those which are really produced* by them, the effects of each being ascribed to the other; a mistake capable of producing much disappointment and detriment.

Having made myself certain that the dyers' spirit or nitro-muriatic solution of tin, without tartar, would only dye a crimson with cochineal, I was induced to make an experiment therewith, instead of the muriate of tin, at the dye-house of the late Mr. Seward in Goswell-street, and with views similar to those which directed the experiments before made at Messrs. Goodwin. A piece of baize was accordingly boiled one hour and a quarter with the usual portion of nitro-muriatic solution of tin, (which had been prepared by Mr. Seward,) and with about $\frac{1}{40}$ of its weight of Quercitron bark, without any tartar. After which it was taken out dyed of a bright yellow, though paler than it would have been with the muriate of tin. The baize being rinced, and the dying vessel emptied, and then filled a second time with clean water, about four-fifths of the cochineal usually employed for the like quantity of baize, and a farther suitable proportion of the solution of tin, were put into it, and the baize being dyed therein, as usual, took what was allowed to be a good scarlet. Mr. Seward, however, did not seem so fully convinced, as I had expected, of the advantage of compounding a scarlet in this way from the cochineal crimson and Quercitron yellow; and probably the experiment had not been attended with any very manifest success, or saving of cochineal, because the nitro-muriatic solution of tin,

tin, which had produced but a pale yellow with the Quercitron bark, had alſo acted more feebly in raiſing or exalting the cochineal colour than it uſually does when aſſiſted with tartar, which conſiſts of a portion of vegetable alkali combined with an exceſs of its own peculiar acid; and therefore, whenever it is mixed with a ſolution of tin by any of the mineral acids, the tartar will be decompoſed; becauſe the mineral acids, by their ſuperior attraction for, will unite with its alkaline baſis, and diſengage an additional portion of the tartarous acid, which will then unite with the metallic calx, previouſly abandoned by the mineral acid, and thus produce a *tartrite of tin*, which laſt, in the uſual way of dying ſcarlet, inclines the cochineal crimſon to a yellow hue, and at the ſame time, (as I have ſince found,) exalts its colour more than the nitro-muriatic ſolution of tin alone would be able to do; and it is only this production of a tartrite of tin that has obviated the ill effects which otherwiſe muſt have reſulted from the ſulphuric acid frequently contained in the common aqua-fortis uſed by the ſcarlet dyers. Not many years have elapſed indeed, ſince money was obtained from ſeveral eminent dyers in London, for a ſecret to *ſtrengthen* their aqua-fortis, which they were to do by adding to it a portion of oil of vitriol; and though they were ſoon induced no longer to employ this ſecret, it may be concluded that they did not pay money for it without ſome previous trials, and at leaſt an appearance of benefit from its uſe; and certainly a moderate portion of vitriolic acid would in this way operate a ſaving of the dearer nitric acid, ſince its action would be exerted only in

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decompoſing the tartar, by uniting with its alkaline baſis, and producing a ſulphate of potaſh or vitriolated tartar, which ſeems no more hurtful to the ſcarlet dye than the nitrate of potaſh or ſalt-petre, which the nitric acid produces in the ſame way, where there is no vitriolic to take its place, in conſequence of its ſuperior attraction for the alkaline baſis of tartar.

Though I had hitherto failed in my endeavours to compoſe a ſcarlet colour with advantage, ſo as to ſave that part of the cochineal which appeared to be miſapplied, by being converted to the yellowiſh hue in the uſual proceſs, I had nevertheleſs full confidence in my former reaſoning on this ſubject, and employed myſelf from time to time in ſearching after more ſuitable means for attaining this end. Some of my earlieſt experiments with a ſolution, or rather a calcination of tin by the ſulphuric acid, had ſhewn me that this preparation was very unſuitable for my purpoſe, becauſe it really exerted a deſtructive action on the cochineal colour, by reducing it from a crimſon down to a kind of ſalmon colour, which indeed was the higheſt colour produced on cloth by dying it with cochineal and ſulphate of tin; I therefore diſcarded the uſe of ſulphuric acid for diſſolving tin, until particular circumſtances led me ſome time after to diſſolve a portion of it by the muriatic acid, combined with about one-fourth of its weight of oil of vitriol; and by trying this ſolution, I found that it produced very good effects in dying, without any appearance of that corroſive property which had acted ſo miſchievouſly in the experiments made with tin, diſſolved by muriatic acid only. I was therefore encouraged to make and try other ſolutions of that metal by the ſame acids, united in various proportions; and have at length found reaſon to prefer a ſolution made by diſſolving after the rate of about fourteen ounces of tin in a mixture of two pounds of oil of vitriol, (of the uſual ſtrength,) with about three pounds of muriatic acid. That which I have uſed was ſtrong enough, with a ſand-heat, to diſſolve one-third of its weight of tin, and rather more than one-fourth of its weight of *zinc*, which laſt metal is moſt commodious for aſcertaining the ſtrength of muriatic acid, becauſe it diſſolves therein very rapidly in the common heat of the atmoſphere. The muriatic acid ſhould be firſt poured upon a large quantity of granulated tin, in a large glaſs receiver, and the oil of vitriol afterwards added ſlowly; and theſe acids mixed ſhould be left to ſaturate themſelves with tin, which they will do in time without any artificial heat; but the ſolution will be rapidly promoted by a ſand heat.

This ſolution contained but little more than half as much tin as the muriatic ſolution which had been uſed in the firſt experiment made at the dye-houſe of Meſſrs. Goodwin and Co., yet the metallic part of it exiſted in a ſtate ſo much more ſuitable for the purpoſes of dying, that a given quantity of it would produce much better effects than a like quantity of muriatic ſolution, containing nearly twice as much of the metal, and without any corroſive property, capable of doing the leaſt miſchief, unleſs uſed in much greater proportions than ever can be wanted for dying.

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The murio-ſulphuric ſolution of tin, made in theſe proportions, will be perfectly tranſparent and colourleſs; and will probably remain ſo for many years, without becoming turbid, or ſuffering by any precipitation of the metal; at leaſt none has appeared in ſome which I have kept for more than three years. It will produce full twice as much effect as the dyers' ſpirit, or nitro-muriatic ſolution of tin, with leſs than a third of the expence. It has moreover the property of raiſing the colours of, I believe, all adjective dyes, more than the dyers' ſpirit, and full as much as the tartrite of tin, without changing the natural crimſon of cochineal towards the yellowiſh hue; and therefore, after having made a great number of experiments with it, I think myſelf warranted in ſtrongly recommending this murio-ſulphate of tin for dying the compound ſcarlet colour already deſcribed, (with the cochineal crimſon and Quercitron yellow,) for which it will be found highly effectual and œconomical.

For this ſpecies of ſcarlet nothing is neceſſary but to put the cloth, ſuppoſe 100lb. weight, into a proper tin veſſel, nearly filled with water, in which about eight pounds of the murio-ſulphuric ſolution of tin have been previouſly mixed, to make the liquor boil, turning the cloth as uſual through it, by the winch, for a quarter of an hour; then turning the cloth out of the liquor, to put into it about four pounds of cochineal, and two pounds and a half of Quercitron bark in powder, and having mixed them well, to return the cloth again into the liquor,

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making it boil, and continue the operation as ufual until the colour be duly raifed, and the dying liquor exhaufted, which will be the cafe in about fifteen or twenty minutes; after which the cloth may be taken out and rinced as ufual. In this way the time, labour, and fuel, neceffary for filling and heating the dying veffel a fecond time, will be faved; the operation finifhed much more fpeedily than in the common way; and there will be a faving of all the tartar, as well as of two-thirds of the coft of fpirit, or nitro-muriatic folution of tin, which for dying 100lb. of wool, commonly amounts to 10s.; whereas, 8lb. of the murio-fulphuric folution will only coft about 3s. There will be moreover a faving of at leaft one-fourth of the cochineal ufually employed, (which is generally computed at the rate of one ounce for every pound of cloth,) and the colour produced will certainly not prove inferior in any refpect to that dyed with much more expence and trouble in the ordinary way. When a rofe-colour is wanted, it may be readily and cheaply dyed in this way, only omitting the Quercitron bark, inftead of the complex method now practifed of firft producing a fcarlet, and then changing it to a rofe by the volatile alkali contained in ftale urine, fet free or decompofed by pot-afh or by lime: and even if any one fhould ftill *unwifely* choofe to continue the practice of dying fcarlet without Quercitron bark, he need only employ the ufual proportions of tartar and cochineal, with a fuitable quantity of the murio-fulphate of tin, which, whilft it cofts fo much lefs, will be more effectual than the dyers' fpirit.

Several

Several hundreds of experiments warrant my aſſertion, that at leaſt a fourth part of the cochineal generally employed in dying ſcarlet, may be ſaved by obtaining ſo much yellow as is neceſſary to compoſe this colour from the Quercitron bark; and indeed nothing can be more ſelf-evident, than that ſuch an effect, *ceteris paribus*, ought neceſſarily to reſult from this combination of different colouring matters, ſuited to produce the compound colour in queſtion. Let it be recollected that the cochineal crimſon, though capable of being changed by tartar towards the yellow hue on one hand, is alſo capable by other means of being changed towards a blue on the other, and of thereby producing a purple without indigo or any other blue colouring matter: yet I am confident that nobody would believe a pound of cochineal ſo employed capable *alone* of dying as much cloth, of any particular ſhade of purple, as might be dyed with it, if the whole of its colouring matter were employed ſolely in furniſhing the crimſon part of the purple, whilſt the other (blue) part thereof was obtained from indigo. To ſay that a pound of cochineal *alone* could produce as much effect or colour as a pound of cochineal and a pound of indigo *together*, would be an improbability much too *obvious* and *palpable* for human belief; and there certainly would be a ſimilar improbability in alleging, that a pound of cochineal, employed in giving another compound colour (ſcarlet), could alone produce as much effect as a pound of cochineal and a pound of Quercitron bark, when the colour of this laſt was employed only in furniſhing one of the component parts of the ſcarlet, for which a conſiderable portion of the colouring matter of the cochineal muſt otherwiſe have been expended, which certainly happens in the new mode of dying ſcarlet, becauſe the colour produced with an addition of the Quercitron yellow inclines no more towards a yellow, than the ſcarlet produced by yellowing a part of the cochineal colour in the uſual method with tartar. I retain, therefore, at this moment, as much confidence as I ever had in the reality and importance of my propoſed improvements in this reſpect *.

The ſcarlet compoſed of cochineal crimſon and Quercitron yellow, is moreover attended with this advantage, that it may be dyed upon wool and woollen-yarn without any danger of its being changed to a roſe or crimſon, by the proceſs of fulling, as always happens to ſcarlet dyed by the uſual means. This laſt being in fact nothing but a crimſon or roſe colour, yellowed by ſome particular action or effect of the tartar, is liable to be made crimſon again by the application of many chymical agents, (which readily overcome the changeable yellow produced by the tartar,) and particularly by calca-

* Of the benefit which I formerly expected to obtain by employing pot-aſh to extract a part of the cochineal colour, which water alone did not appear capable of extracting, it muſt be remarked that I have ſometime ſince convinced myſelf of its being an illuſion; for, by repeated trials, I have found that the ſolid parts of powdered cochineal remaining after it has been boiled with the ſolution of tin, as in the common dying proceſs, yield no colour worth notice, upon the application of pot-aſh, the ſolution of tin enabling the water to extract the colour ſufficiently; ſo that in truth there is no ſuch waſte of cochineal colour as I had ſuppoſed in the uſual way of employing that drug.

reous earths, ſoap, alkaline ſalts, &c. But where the cochineal colouring matter is applied and fixed merely as a *crimſon* or *roſe* colour, and is rendered ſcarlet by ſuperadding a very *permanent Quercitron yellow*, capable of reſiſting the ſtrongeſt acids and alkalies, (which it does when dyed with ſolutions of tin,) no ſuch change can take place, becauſe the cochineal colour having never ceaſed to be crimſon, cannot be rendered more ſo, and therefore cannot ſuffer by thoſe impreſſions or applications which frequently change or ſpot ſcarlets dyed according to the preſent practice.

There is alſo a ſingular property attending the compound ſcarlet dyed with cochineal and Quercitron bark; which is, that if it be compared with another piece of ſcarlet dyed in the uſual way, and both appear by day-light *exactly of the ſame ſhade*, the former, if they be afterwards compared by candle-light, will appear to be at leaſt ſeveral ſhades higher and fuller than the latter; a circumſtance of ſome importance, when it is conſidered how much this and other gay colours are generally worn and exhibited by candle-light during a conſiderable part of the year.

To illuſtrate more clearly the effects of the murio-ſulphuric ſolution of tin with cochineal in dying, I ſhall ſtate a very few of my numerous experiments therewith; obſerving, however, that they were all ſeveral times repeated, and always with ſimilar effects.

1ſt, I boiled one hundred parts of woollen cloth in water, with eight parts of the murio-ſulphuric ſolution of tin, during the ſpace of ten or fifteen minutes; I then added to the ſame water four parts of cochineal, and two parts and a half of Quercitron bark in powder, and boiled the cloth fifteen or twenty minutes longer; at the end of which it had nearly imbibed all the colour of the dying liquor, and received a very good, even, and bright ſcarlet. Similar cloth dyed of that colour at the ſame time in the uſual way, and with a fourth part more of cochineal, was found upon compariſon to have ſomewhat leſs body than the former; the effect of the Quercitron bark in the firſt caſe having been more than equal to the additional portion of cochineal employed in the latter, and made yellow by the action of tartar.

2d, To ſee whether the tartrite of tin would, beſides yellowing the cochineal crimſon, contribute to raiſe and exalt its colour more than the murio-ſulphate of that metal, I boiled one hundred parts of cloth with eight parts of the murio-ſulphuric ſolution, and ſix parts of tartar, for the ſpace of one hour; I then dyed the cloth, *unrinced*, in clean water, with four parts of cochineal, and two parts and a half of Quercitron bark, which produced a bright aurora colour, becauſe a double portion of yellow had been here produced, firſt by the Quercitron bark, and then by the action of tartar upon the cochineal colouring matter. To bring back this aurora to the ſcarlet colour, by taking away or changing the yellow produced by the tartar, I divided

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the cloth whilst unrinced into three equal parts, and boiled one of them a few minutes in water slightly impregnated with pot-ash; another in water with a little ammoniac; and the third in water containing a very little powdered chalk, by which all the pieces became scarlet; but the two last appeared somewhat brighter than the first, the ammoniac and chalk having each rosed the cochineal colour rather more advantageously than the pot-ash. The best of these, however, by comparison, did not seem preferable to the compound scarlet dyed without tartar, as in the preceding experiment; consequently this did not seem to exalt the cochineal colour more than the murio-sulphate of tin; had it done so, the use of it in this way would have been easy without relinquishing the advantages of the Quercitron yellow.

3d, I boiled one hundred parts of woollen cloth with eight parts of the murio-sulphuric solution of tin, for about ten minutes, when I added four parts of cochineal in powder, which by ten or fifteen minutes more of boiling, produced a fine crimson. This I divided into two equal parts, one of which I yellowed or made scarlet by boiling it for fifteen minutes with a tenth of its weight of tartar in clean water; and the other, by boiling it with a fortieth of its weight of Quercitron bark, and the same weight of murio-sulphuric solution of tin; so that in this last case there was an addition of yellow colouring matter from the bark, whilst in the former no such addition took place, the yellow necessary for producing the scarlet having been wholly gained by a change and diminution of

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the cochineal crimfon; and the two pieces being compared with each other, that which had been rendered fcarlet by an addition of Quercitron yellow, was, as might have been expected, feveral fhades fuller than the other.

4th, I dyed one hundred parts of woollen cloth fcarlet, by boiling it firft in water with eight parts of murio-fulphate of tin, and twelve parts of tartar, for ten minutes, and then adding five parts of cochineal, and continuing the boiling for fifteen minutes. This fcarlet cloth I divided equally, and made one part crimfon, by boiling it with a little ammoniac in clean water; after which I again rendered it fcarlet, by boiling it in clean water, with a fortieth of its weight of Quercitron bark, and the fame weight of murio-fulphate of tin; and this laft, being compared with the other half, to which no Quercitron yellow had been applied, was found to poffefs much more colour, as might have been expected. A piece of the cloth, which had been dyed fcarlet by cochineal and Quercitron bark, as in the firft experiment, being at the fame time boiled in the fame water with ammoniac, did not become crimfon, like that dyed fcarlet, without the bark.

In this way of compounding a fcarlet from cochineal and Quercitron bark, the dyer will at all times be able, with the utmoft certainty, to produce every poffible fhade between the crimfon and yellow colours, by only increafing or diminifhing the proportion of bark. It has indeed been ufual at times when fcarlets, approaching nearly to the aurora colour, were in fafhion,

to

to ſuperadd a fugitive yellow either from turmeric, or from what is called young fuſtic (Rhus Cotinus); but this was only when the cochineal colour had been previouſly *yellowed as much as poſſible by the uſe of tartar*, as in the common way of dying ſcarlet; and therefore that practice ought not to be confounded with my improvement, which has for its object to preclude the loſs of any part of the cochineal crimſon, by its converſion towards a yellow colour, which may be ſo much more cheaply obtained than the Quercitron bark.

By ſufficient trials, I have ſatisfied myſelf that the cochineal colours, dyed with the murio-ſulphuric ſolution of tin, are in every reſpect at leaſt as durable as any which can be dyed with any other preparation of that metal; and they even ſeem to withſtand the action of boiling ſoap ſuds ſomewhat longer, and therefore I cannot avoid earneſtly recommending its uſe for dying roſe and other cochineal colours, as well as for compounding a ſcarlet with the Quercitron bark.

I have thus freely given the reſults of a multitude of experiments, which have coſt me ſome money, with not a little time and meditation; and I have given them without the leaſt idea of ever claiming any kind of remuneration from the public; and though it may be ſome time before the truth and importance of what I here offer are fully recognized, I am confident this will happen ſooner or later; and by putting it into every one's power to bring my ideas to the teſt

teſt of experience, I ſhall have at leaſt done my duty.

It remains, however, yet for me to communicate the effects of a conſiderable number of earthy and metallic baſes upon the colouring matter of cochineal, which I ſhall ſtate as briefly as poſſible, omitting all detail reſpecting proportions and modes of conducting the dying operations, which are to be underſtood as having been conformable to the common practice where nothing is mentioned to the contrary.

Woollen cloth, dyed with cochineal and nitrate of tin, produced a fine crimſon, and this, boiled in the ſame liquor with tartar, was changed to a good ſcarlet. A ſimilar, but rather better effect was produced by tin diſſolved immediately in a mixture of aqua-fortis and tartar. The ſcarlet given by this tartaro-nitrate of tin appeared highly beautiful.

Tin put into aqua-fortis, with a conſiderable portion of refined ſugar, afforded a very thick adheſive ſolution, which aſſumed a blackiſh brown colour, like that of *burnt ſugar*, and being tried as a mordant in dying, it was found incapable of fixing the cochineal or any other colours. The tin in this ſtate did not ſeem fitted to combine with the fibres of the cloth, and the ſugar had manifeſtly ſuffered a kind of combuſtion. Spirit of wine, put with tin into aqua-fortis, alſo rendered the ſolution unfit to combine with wool, or ſerve as a mordant.

Tin,

Tin, calcined with an equal quantity of ſalt-petre in a red-hot crucible, being thrown into water, afforded a milky ſolution, taſting very ſenſibly of the alkaline part of the ſalt-petre, and evidently ſuſpending a conſiderable portion of the metallic calx. Cloth boiled in water with ſome of this ſolution, then rinced, and dyed with cochineal, took a crimſon, inclining to the purple; and this, boiled in the ſame liquor with tartar, was changed to ſcarlet.

I poured two pounds of aqua-fortis, with an equal weight of water, upon a large quantity of granulated tin, and leaving them together during the three ſummer months of 1790, I afterwards found near a pound of the calx of tin collected in lumps at the bottom of the glaſs veſſel. This being ſeparated and dried, ſome of it was finely powdered and *thoroughly waſhed*; then putting it with an equal weight of cochineal into water, I boiled cloth therein, which took a full equal crimſon, ſomewhat deficient in brightneſs. Tartar being added to the liquor, and the cloth farther boiled therein, it became of a good ſcarlet. Lemon juice, uſed inſtead of tartar, produced the like effect. By ſubſtituting cauſtic volatile alkali for tartar and lemon juice, a crimſon, greatly inclining to purple, was produced. The oxide of tin, therefore, does not act in all caſes *merely as ſuch*, but its effects often depend on triple, quadruple, and ſometimes even more complex combinations, in which different ſaline and other parts of the compound remain permanently united, at leaſt where the ſhades of colour depending on them are found permanent. It is thus that ſea-ſalt, and other purely ſaline

matters,

matters, which having no earthy or metallic basis, cannot become the basis of any adjective colour, produce *lasting* effects in modifying and varying the complexions of different colours.

It must, however, be observed, that though the calx of tin, after being thoroughly washed and dried, was capable of dying a crimson on woollens with cochineal, and a scarlet, where either tartar, lemon juice, or Quercitron bark were added, it would not permanently combine with or become the basis of these colours upon cotton; and indeed on woollen it was only the finer particles of the calx which really combined with the colouring matter and the wool, the grosser being always distinctly found at the bottom of the dying vessel; and when I attempted to impregnate woollen cloth with the oxide of tin separately, by boiling them together, I always found, on rincing the cloth, and endeavouring to dye it with cochineal in a different vessel, that the oxide had not penetrated or united with the wool, so as to afford a basis for raising and fixing the colour, it being necessary for this purpose that both the oxide and the colouring matter should be mixed together in the dying vessel, and exert their mutual attractions for and upon each other, before they could be properly taken up by the cloth; and this was done better after they had been previously mixed and left together for several hours.

One ounce of the calx of tin before mentioned, unwashed, being dissolved in three ounces of muriatic acid, and woollen cloth being dyed

 with

with a tenth of its weight of this ſolution, and a twentieth of cochineal, it took but a very languid pale red colour. The calx of tin, which was immediately decompoſed upon its intermixture with water, manifeſted very little diſpoſition to penetrate or combine with the fibres of the wool; and after long boiling the greater part of it, and of the colouring matter, remained ſuſpended in the dying liquor. Nearly ſimilar effects reſulted from a ſolution of tin by the oxygenated muriatic acid.

Cochineal with a ſolution of tin by muriatic acid, dyed a beautiful crimſon; and with a ſolution of that metal, by a mixture of tartar and muriatic acid, a beautiful ſcarlet.

Cochineal with tin diſſolved by muriatic acid and the acid of tar mixed, produced a dark crimſon; and with tin, and a little manganeſe diſſolved in muriatic acid, it produced a very bluiſh crimſon.

Cochineal with tin diſſolved by muriatic acid and borax mixed, dyed a very good crimſon.

Cochineal with tin calcined by the long continued action of ſulphuric acid, dyed a ſalmon colour; and with a recent ſolution of tin it produced a reddiſh ſalmon colour, inclining a little to the crimſon. A like colour was produced with tin diſſolved by equal parts of ſulphuric and nitric acids mixed.

Oil of vitriol having been poured upon tartar and granulated tin, the mixture immediately be-

came

came black, by the action of the ſulphuric acid upon the carbonic baſis, which, with hydrogene and oxygene, are the conſtituents of tartar. Cloth dyed with a tartaro-ſulphuric ſolution of tin thus made, and cochineal, took an aurora colour.

Tin diſſolved by the pure acid of tartar, ſeparated from its alkaline baſis, (by the means uſually employed for that purpoſe,) dyed with cochineal on cloth a very beautiful ſcarlet, inclining a little to the aurora. A ſimilar colour was produced by water ſaturated with cream of tartar, in which granulated tin had been kept ſix weeks.

Tin very readily diſſolves by pure citric acid, and even by lemon juice; and the ſolution newly made, dyes with cochineal a moſt beautiful ſcarlet, inclining, like the preceding, a little to the aurora. Indeed, I have repeatedly found that the citric acid with tin, acts at leaſt as efficaciouſly as that of tartar in yellowing the cochineal crimſon. Nothing can exceed the beauty of ſcarlet dyed with the citrate of tin.

Granulated tin, diſſolved by ſtrong vinegar, acquired a very particular, and ſomewhat of an unpleaſant ſmell; and with cochineal it dyed cloth of a ſcarlet, inclining a little to the crimſon colour.

Tin diſſolved by acid of tar produced with cochineal a colour between the ſcarlet and crimſon ſhades.

Phoſ-

Phoſphoric acid produced a permanently tranſparent and colourleſs ſolution of tin; and this (phoſphate of tin) with cochineal dyed an aurora colour.

Tin diſſolved by fluoric acid, produced with cochineal a very good ſcarlet.

Such were the effects produced on woollen cloths by different preparations of tin, as baſes for dying with cochineal. With other baſes, cochineal gave the following colours to wool, *viz.*

With nitro-muriate of platina, a red; which, by the addition of chalk, became a cheſnut colour.

With nitro-muriate of gold, a reddiſh brown.

With nitrate of ſilver, a dull red; and with muriate of ſilver, a lively reddiſh orange.

With the acetite of lead, a purple, inclining to the violet; and with nitrate of lead, a delicate lively colour, between the red and cinnamon, but inclining moſt to the former. A little murio-ſulphate of tin, added to the liquor in which this laſt was dyed, ſoon changed it to a good crimſon.

With either the ſulphate, nitrate, muriate, or acetite of iron, cochineal produces a dark violet, and even a full black colour, when employed in ſufficient quantity.

All the preparations of copper appear to ſadden and debaſe the colouring matter of cochineal; and all thoſe of mercury, which I have tried, do this in much greater degrees; moſt of them, whilft they debafe the colour, feem to annihilate a confiderable part of it.

With nitrate of zinc, cochineal dyed a lively ftrong lilac colour; and,

With muriate of zinc, a colour like the preceding, but inclining a little more to the purple. Probably the iron ufually contained in zinc may have contributed in thefe inftances to incline the cochineal crimfon fo much to the blue or violet fhades, fince a purer oxide of zinc, the lapis caliminaris, being diffolved in muriatic acid, dyed (with cochineal) a fcarlet but very little inferior to that commonly produced with the nitro-muriate of tin and tartar; and upon adding a little murio-tartrite of tin to the dying liquor, it foon produced a very beautiful fcarlet. The pure oxide of zinc therefore feems to approach neareft to that of tin, in exalting the colouring matter of cochineal.

With different folutions of bifmuth, cochineal produced various fhades of lilac; fome of them very lively and delicate; but all preparations of this femi-metal, inftead of difplaying and exalting the cochineal colour, tended to render a part of it latent. The oxide of bifmuth, diffolved in ftrong vinegar, did this lefs than moft of the other preparations; it dyed with cochineal a pretty good purple, and the murio-fulphate of bifmuth, a falmon colour.

With nitrate of cobalt, cochineal dyed a good purple.

With nitrate of nickle, a dark lilac, inclining to the violet.

With sulphate of manganese, an orange; and

With the nitrate of manganese, a colour resembling the madder red.

With crude antimony, dissolved by nitric acid, cochineal dyed a scarlet very much like that dyed with lapis caliminaris dissolved by muriatic acid, and very little inferior to the best scarlets given with the tin basis; and

With Macquer's arsenical neutral salt, or the acidulous arseniate of pot-ash, cochineal dyed a lively good purple.

Such were the effects of different metallic bases in dying with cochineal on woollens. It remains for me shortly to offer a few observations on the effects of the several kinds of earths, as bases for the cochineal colouring matter upon wool.

The use of sulphate of alumine, or common alum, for this purpose, is well known. The alumine, or earth of alum, (obtained by decomposing and precipitating it by pot-ash from water, saturated with alum,) when thoroughly washed, dried, and finely powdered, did not seem capable, in repeated trials, of fixing or serving as a basis of the cochineal colour on wool. In this respect it differed materially from the powdered calx of tin.

The same powdered alumine, however, being boiled up with cream of tartar, was so far dissolved by its acid, that with cochineal it dyed a good crimson, though not much better than

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what may be produced with the ſulphate of alumine.

The ſame powdered earth of alum, diſſolved by lemon juice, dyed with cochineal a very good rich full crimſon.

The ſame powdered earth of alum, diſſolved by nitric acid, (and forming nitrate of alumine,) produced a good red, inclining to the crimſon.

The ſame diſſolved in muriatic acid (muriate of alumine) dyed a crimſon, differing but little from that produced with common alum.

Lime water, with cochineal, dyed a purple, which took but ſlowly, and required long boiling.

Sulphate of lime, or lime diſſolved by ſulphuric acid, dyed a full dark red.

Nitrate of lime, or lime diſſolved by nitric acid, dyed a lively red, approaching to ſcarlet.

Muriate of lime, with cochineal, dyed a purple.

Cloth boiled in water with *nitrate of lime*, and then dyed in clean water with cochineal and tin, diſſolved by aqua-fortis and tartar mixed, received a good ſcarlet.

Cloth boiled with chalk and alum, and then dyed in clean water with cochineal, took a good crimſon, inclining to the bluiſh ſhade.

Sulphate

Sulphate of barytes, or ponderous ſpar, not being ſoluble in water, could not be tried.

Muriate of barytes, or the earth of ponderous ſpar combined with muriatic acid, as a baſis for the cochineal colour, dyed a good lively purple; and

Nitrate of barytes dyed a colour nearly ſimilar, but inclining a little more to the crimſon.

Magneſia alone did not combine ſufficiently with the fibres of cloth, and with the colouring matter of cochineal, to ſerve as a baſis for dying.

But magneſia diſſolved by ſulphuric acid, (forming Epſom ſalt,) dyed a lively purple with cochineal, though it took but ſlowly, and required long boiling; and acetite of magneſia dyed a lilac colour.

The ſiliceous earth, or powdered flints diſſolved by a violent heat in a crucible with pure cauſtic alkali or pot-aſh, was tried as a baſis for the cochineal colour. At firſt the fibres of the cloth did not ſeem to have ſufficient attraction for the ſiliceous baſis and the colouring matter, to attach and fix them properly; but on adding a little ſulphuric acid, ſo as to decompoſe and neutralize a part of the alkali, which had diſſolved and was combined with the ſiliceous earth, the colour took freely, and roſe to a *full rich pleaſing purple*, in which the red or crimſon predominated conſiderably; and this colour afterwards proved ſufficiently durable.

It appears, therefore, that befides the metallic oxides and folutions, all the different kinds of earth, *i. e.* the aluminous, calcareous, and filiceous, together with thofe of magnefia, and of barytes or ponderous fpar, are capable of fixing and ferving as bafes of the cochineal colouring matter; and we fhall hereafter find, that they are capable of doing the fame to other adjective colours; a fact never before afcertained, though of great importance, as well in refpect of the practical improvements which it may produce, as of the general principles and conclufions to which it may lead us on this fubject.

I have repeated nearly all the foregoing experiments with filk, inftead of wool, and generally with effects lefs advantageous. Cochineal indeed, with the aluminous bafis, dyes the crimfon colour as well and as durably on filk as on wool, and the modes of producing a very lafting crimfon by thefe means are well known. The oxides or folutions of tin, however, do not fix and reflect the cochineal colour on filk with the fame degree of fullnefs and luftre as upon wool; probably becaufe the former of thefe fubftances has lefs attraction than the latter, for the calx of tin and the colouring matter of cochineal combined together; and it has therefore been found impoffible to dye a good lively fcarlet on filk by the means which communicate that colour to wool.

The late Monf. Macquer indeed, about the year 1768, pretended to have difcovered the means of dying a fcarlet upon filk by a procefs which

which he publiſhed in the Memoirs of the Royal Academy of Sciences for that year. According to that proceſs, he began by dying the ſilk firſt of a yellowiſh orange colour, with annotta applied in the uſual way; then he ſoaked it for half an hour in a diluted ſolution of tin, made by a mixture of two parts of the nitric, with one of the muriatic acid; after which the ſilk was taken out, moderately preſſed, and rinced in clean water, though he afterwards found it better to omit the rincing. To dye the ſilk, when thus impregnated with nitro-muriate of tin, he prepared a bath, by boiling from two to four ounces of cochineal, and a quarter of an ounce of cream of tartar, for each pound of ſilk, ſome minutes in water; after which he added cold water, until the heat of the liquor was reduced to what the hand could bear, and then put in the ſilk, and dyed it as uſual, gradually raiſing the heat of the dying liquor, ſo as at laſt to make it boil for a ſingle minute. I have ſeveral times repeated this proceſs, but always found the colour produced by it very inferior to the ſcarlets uſually dyed on woollen cloth; and Mr. Berthollet informs us, that this was alſo the caſe at the trials which Mr. Macquer himſelf made of his proceſs at the dye-houſe of the Gobelines; and in truth there was nothing of any importance in Mr. Macquer's ſuppoſed diſcovery. It ſeems indeed to have been chiefly borrowed from a proceſs publiſhed by Schele in 1751, excepting ſo far as relates to the colour firſt given with annotta, and excepting a difference in the proportion of muriatic acid for diſſolving the tin; a difference, however, which did not render the ſolution in any reſpect more efficacious.

If the murio-ſulphuric ſolution of tin, herein before deſcribed, be diluted with about five times its weight of water, and ſilk be ſoaked in it for the ſpace of two hours, then taken out, moderately ſqueezed or preſſed, afterwards partly dried, and then dyed as uſual in a bath prepared with cochineal and Quercitron bark, in the proportion of four parts of the former to three of the latter, it will receive a colour approaching very much to a ſcarlet; and this may be made to receive more body by a farther ſlight immerſion into the diluted murio-ſulphate of tin, and a ſecond dying in the bath from cochineal and Quercitron bark; and if afterwards a little of the red colouring matter of ſafflower be ſuperadded by the uſual mode of applying it, a good ſcarlet may be produced. By omitting the Quercitron bark, and dying the ſilk (prepared as before mentioned) with cochineal only, a very lively roſe colour will be produced; and this may be yellowed ſo as nearly to approach the ſcarlet, by adding a large proportion of tartar to the cochineal in the dying veſſel.

With lime water as a mordant, cochineal gave to ſilk a very agreeable purple; with muriate of barytes, a lively delicate lilac colour; with murio-ſulphate of biſmuth, a ſalmon colour; and with nitrate of cobalt, a very lively and beautiful purple; with nearly all the other metallic and earthy baſes, cochineal produced ſimilar but paler colours on ſilk than on wool.

Reſpecting cotton, my readers will recollect that I have already (at page 195) noticed the little attraction which this ſubſtance exerts upon the

the cochineal colouring matter, united with the ſolutions or oxides of tin. To illuſtrate this, Monſ. du Fay cauſed a piece of cloth to be manufactured from a mixture of wool and of cotton, which having undergone the uſual proceſs for dying ſcarlet, became, as he deſcribes it, " marbrée de couleur de feu & de blanc," (marbled with white and fire colours,) the cotton remaining perfectly white, though the wool was dyed ſcarlet; and he found a like want of attraction between cotton and the colouring matters of kermes, gum lacca, &c. He moreover found that a ſkain of white woollen yarn, and another of cotton, being at the ſame time, and in an equal degree, ſubmitted to the action of the ſame preparation and dying liquors which are commonly employed for ſcarlet, the woollen yarn received the moſt beautiful ſcarlet, or, as he terms it, "*fire colour*," whilſt the cotton remained as white as at firſt *. Similar effects have frequently occurred to me, and I have clearly perceived them to ariſe, not becauſe the cotton is not capable of imbibing the ſcarlet dye, but becauſe, having a weaker attraction for it than that which wool exerts on the particles of that dye, the latter *draws and excluſively appropriates to itſelf* all the colour contained in the dying liquor; though when cotton is ſubjected to the ſame proceſs by itſelf, freed from the interference of a ſuperior attraction from wool, it takes a ſcarlet colour, as I know by repeated trials, more ſlowly indeed, and paler, than that which is uſually imbibed by woollen cloth. It is, perhaps, owing to this weaker attraction be-

* See Mem. de l'Acad. R. des Sciences, &c. 1737.

tween

tween the fibres of cotton and the ſcarlet dye, that the latter is ſo much leſs permanent on cotton than on wool; and it is alſo from this want of ſufficient attraction, that the cochineal colour is found to take moſt beneficially on cotton, when the baſis has been *firſt applied ſeparately*.

Scheffer, in 1751, recommended the dying of ſcarlet on cotton in this way, by firſt ſoaking it in a diluted nitro-muriate of tin, and afterwards dying it with cochineal; but the colour being fugitive, little or no uſe was ever made of the proceſs; though the late Dr. Berkenhout probably availed himſelf of it ſome years afterwards, when he pretended to have diſcovered the means of dying "ſcarlet, crimſon, and "other colours, upon cotton and linen;" and though his proceſs was not materially different from that of Scheffer, nor in any reſpect preferable to it, he found means to obtain 5000l. ſterling from the Britiſh government, as a reward for making it public *. But as no uſe ever has

* Dr. Berkenhout's proceſs having, I believe, never been publiſhed, I ſhall ſubjoin the account of it, which was "communicated by order of the Lords of the Treaſury to "the Company of Dyers in the City of London, the 26th "of Auguſt 1779;" *viz.*

"Cotton or linen, either in yarn or piece, ſhould be perfectly wet with hot water, and then wrung out, as is the common practice.

"This being done, it muſt be perfectly ſoaked in a ſolution of tin, diluted with an equal quantity of clear ſoft water.

"The cotton or linen being ſo far prepared, muſt be wrung out, but not forcibly; then it is to be nearly dried, laying has been, or is likely to be made of this ſuppoſed diſcovery, I muſt hope, and indeed I

laying horizontally upon a hurdle, with a double linen ſheet between, and covered with the ſame.

"The ſolution of tin being for ſcarlet, muſt be made of nitrous acid, and not of aqua-fortis; but for crimſon, aqua-fortis muſt be uſed; and the bloom is to be given, after it comes out of the dye, by a ſmall quantity of ſal-ammoniac and pearl aſhes diſſolved perfectly in warm water; but this water muſt not be more than milk-warm.

"The colouring vat, for the ſcarlet or crimſon, is ſimply cochineal in water, no hotter than the hand will bear; and as vegetable matter receives only the ſmall particles of the colour from the nature of its pores; two ounces to a pound of the materials dyed may be neceſſary; but cotton or linen, freſh prepared, will draw from the ſame vat, heated as before, all the inferior ſhades from ſcarlet and crimſon; and if any colour ſtill remains in the vat, it may be taken out entirely by wool prepared in the uſual manner.

"The ſame preparation of tin ſerves for the green and yellows, with the ſame materials only that are employed by dyers, except the beſt yellow, which is produced from turmaric *.

"It is neceſſary to obſerve, that after the preparation has been made uſe of for ſcarlet or crimſon, the reſidue continues ſufficiently ſtrong for greens or yellows, even after it has been kept a conſiderable time.

"N. B. To make the beſt ſolution of tin with nitrous acid, it is neceſſary to have the ſtrong ſmoaking ſpirit, to which an equal quantity of the pureſt river water muſt be added, and the proportions of the following ingredients are to the weight of ſpirit, $\frac{1}{18}$ of ſal-ammoniac, $\frac{1}{12}$ refined nitre diſſolved by little at a time; in this aqua-regia diſſolve $\frac{1}{8}$ of granulated tin alſo by ſmall quantities, to prevent too great an ebullition, which would weaken the ſolution conſiderably. The ingredients and proportions are the ſame, when a ſolution is to be made with aqua-fortis; but that ſpirit in general will not bear any water when a perfect ſolution is intended."

* Nothing can be more erroneous than this and ſeveral of Dr. Berkenhout's other obſervations.

think

think it probable, that the Doctor had ſome better claim to a national remuneration, though from particular conſiderations it was not brought into public view.

Beſides the fugitive nature of the ſcarlet dyed by Dr. Berkenhout's proceſs, which indeed is calculated to produce only a crimſon, and not a ſcarlet, unleſs ſome yellow colour be ſuperadded by other means, (which he does not mention,) it is liable to injure the texture of the cotton or linen dyed with it, becauſe the nitric calx of tin, applied as the baſis, conſtantly abſorbs oxygene from the atmoſphere, and becomes corroſive, whereas, in the preſent caſe, this effect cannot be counteracted by occaſional waſhings with ſoap.

Mr. Henry ſays, that "if a ſcarlet could be "dyed without the uſe of nitrous acid, the tin "baſis might be employed for this purpoſe on "cotton; but *that acid being requiſite for the* "*production of this beautiful colour*, and being "highly corroſive to colours, this baſis is pre- "vented from being applied to that ſubſtance." —Here this ingenious chymiſt appears to have fallen into the univerſal error of believing, that nothing but a ſolution of tin by nitric, or nitrous acid, can dye a ſcarlet colour with cochineal.

If notwithſtanding the want of ſufficient permanency in the ſcarlet colour dyed with cochineal upon cotton, it ſhould be deemed proper to apply it to that ſubſtance, the beſt way of doing this which I have yet found, is, to ſoak the cotton

ton (previoufly moiftened) for about half an hour in a diluted murio-fulphuric folution of tin, as propofed for filk; then wring or prefs out the fuperfluous part of the folution of tin, and plunge the cotton into water, in which as much, or nearly as much, clean pot-afh has been diffolved, as will neutralize the acid ftill adhering to the cotton, fo as thereby to decompofe the oxide of tin, and caufe it to be more copioufly depofed or fixed in or upon the fibres of the cotton, which being afterwards rinced in clean water, may be dyed with cochineal and Quercitron bark, in the proportions of about four pounds of the former to two and a half or three pounds of the latter. A full bright colour may be given to cotton in this way, which will bear a few flight wafhings with foap, and a confiderable degree of expofure to air. Indeed the yellow part of the colour obtained from Quercitron bark will even bear long boiling with foap, as well as the application of ftrong acids without injury.

Cotton impregnated or printed with the aluminous mordant, as commonly applied by calico-printers for madder reds, will, if dyed with cochineal, receive a very beautiful crimfon colour, capable of bearing feveral wafhings, and of refifting the weather for fome time, though not long enough to deferve the appellation of a faft colour. I think, however, that it is advantageous for calico-printers, in dying madder reds upon the finer cottons or muflins, to add alfo a little cochineal, the crimfon colour of which is admirably calculated to overcome the brownifh

yellow

yellow hue that degrades all madder reds, and arifes from a portion of that particular colouring matter which produces the *fauve* or fawn colour herein-before mentioned, and which unfortunately always exifts in madder. By this addition, the madder reds are rendered much more beautiful, fo long as any part of the cochineal crimfon remained, and afterwards they are no worfe than if it had never been applied.

Cotton printed with iron liquor takes a very full black when dyed with cochineal, but I found this lefs durable than the fame colour dyed from much cheaper matters. A great variety of other colours may be dyed upon cotton impregnated with different metallic or earthy bafes; but as better colours may be more cheaply given by other means, I fhall offer no farther explanations refpecting them.

A ftrong decoction of cochineal, thickened with gum, and mixed with a fuitable proportion of nitrate of alumine, being penciled upon cotton as a pro-fubftantive colour, afforded a very full beautiful crimfon, which ftood fome wafhings, and a confiderable degree of expofure to weather. Several of the different folutions of tin being employed, inftead of the nitrate of alumine, produced very beautiful reds between the crimfon and fcarlet, and by a fmall proportion of Quercitron bark they were made fcarlet. Thefe colours indeed cannot be called faft colours, but they are much more lafting than fome of the fugitive colours too often ufed by

calico-

calico-printers, particularly the yellows from French berries.

Having at this time nothing more to offer reſpecting *animal* adjective colours, I ſhall next proceed to the *vegetable*, beginning with the yellow.

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## CHAP. XII.

### *Of the Properties and Uſes of Quercitron Bark.*

"Il n'y a pas de proprieté plus reſpectable que les de-
"couvertes de l'induſtrie."

BERTHOLLET, *Ann. de Chymie, tome* vi.

THE *Quercitron* bark is produced by the Quercus nigra of Linnæus, which might now be more properly denominated Quercus tinctoria; and is one of the objects of a diſcovery, of which the uſe and application for dying, calico-printing, &c. are excluſively veſted in me, for a term of years, by an act of parliament paſſed in the 25th year of his preſent Majeſty's reign.

The bark of this tree appears to conſiſt of three parts or coats.

1ſt, The epidermis, or external coat, through which the ſeveral excretions of the tree are tranſmitted, which in part at leaſt adhere to its outer ſurface, where they harden, and become almoſt *black*, by condenſation, and probably by an abſorption of oxygene; and hence the Linnæan denomination has originated, that great naturaliſt having had no knowledge of the properties of this bark in dying.

2d, The middle or cellular coat, in which the colouring matter principally reſides; and,

3d, The interior or cortical part, conſiſting chiefly of lamina, formed by the re-union of different veſſels, which become more hard and fibrous, as they are placed neareſt to the woody part of the tree, and have therefore leſs room to contain the colouring matter.

The epidermis, or exterior blackiſh coat, of this bark, affords a yellow colouring matter, which however is leſs pure, and more inclined to a browniſh hue, than that of the other coats or parts; and it ought therefore to be ſeparated by ſhaving. When this is done, and the remaining cellular and cortical parts are ground by mill-ſtones, they will ſeparate partly into a light fine powder, and partly into ſtringy filaments or fibres, which laſt yield but about half as much colour as the powder, and therefore care ſhould be always taken to employ both together, and as nearly as poſſible in their natural proportions, otherwiſe the quantity of colour produced may either greatly exceed or fall ſhort of what is expected. The Quercitron bark thus prepared and proportioned will generally yield as much colour as eight or ten times its weight of the weld plant, (Reſeda luteola, Lin.) and as much as about four times its weight of the chipped

chipped old fuſtic (Morus tinctoria, Lin.): but the colouring matter of the bark in its nature and properties moſt nearly reſembles that of the weld plant; with this advantage however, that it is capable *alone* of producing more cheaply all or very nearly all the effects of every other yellow dying drug; and, moreover, ſome effects which are not attainable by any other means yet known.

The Quercitron colouring matter may be readily extracted by water, even when it is only blood warm; but if the infuſion be ſtrained and left at reſt, a ſmall portion of reſinous matter will ſeparate and ſubſide in the form of a whitiſh powder, capable of giving colours ſimilar to thoſe of the non-ſubſiding parts or particles. The clear infuſion being evaporated, will afford an extract which, when completely dried, has, I think, commonly weighed as much as about one twelfth of the bark from which it was obtained, and yields nearly as much colour as the whole of the bark. But it has been found very difficult to make this extract in any large quantity, ſo as to render it capable of giving colours equal or nearly equal in beauty to thoſe obtained *directly* from the bark itſelf; becauſe if the evaporation be rapidly performed, with a conſiderable degree of heat, the colour always becomes tarniſhed, probably by a combination of Oxygene, producing effects ſimilar to thoſe of a ſlight combuſtion; and if the evaporation be conducted *ſlowly*, the colouring matter ſuffers greatly by another change like that to which the decoction of weld is always liable, and by which it uſually ſpoils by keeping, even in leſs than 24 hours.

There are ſeveral varieties of the Quercus nigra, all containing a portion at leaſt of the ſame ſpecies of colouring matter; but ſome of them, (particularly the Quercus nigra digitata, and the Quercus nigra trifida, both of Marſhal,) which, beſides the yellow, contain a ſpecies of the *fauve* or fawn colour, which tarniſhes the yellow, and in calico-printing occaſions another bad effect, that of ſtaining thoſe parts of the cotton or linen intended to be kept white, ſo as to make the bleaching of them afterwards very difficult. The barks of theſe laſt mentioned varieties have frequently been mixed with that of the better ſort, and ſometimes in conſiderable quantities, (through the ignorance or the inattention of labourers employed in the collection,) ſo as to bring diſcredit upon this new and truly valuable dying drug: but there is reaſon to hope, that ſuch improper mixtures will hereafter be avoided, in conſequence of the very particular inſtructions which have been given for that purpoſe.

The decoction of Quercitron bark appears to be of a yellowiſh brown colour, which is darkened by alkalies, and rendered lighter by acids; allum diſſolved in it, ſeparates but a ſmall portion of the colouring matter, which ſubſides in the form of a deep yellow precipitate. Either the muriate, the nitro-muriate, or the murio-ſulphate of tin, mixed with a decoction of the bark, produces an exceedingly beautiful lively yellow, and occaſions a much more copious precipitation than the allum; probably becauſe the calx of tin unites with the colouring matter in a much larger proportion.

Sulphate of iron diſſolved by a decoction of this bark, produces a copious dark olive precipitate, and the clear ſupernatant liquor remains of a light olive green.

Sulphate of copper in the like decoction, occaſions a precipitation which is of a yellow inclining to the olive, and leaves the ſupernatant liquor of a yellowiſh green.

The effects of other baſes and chymical agents upon the colouring matter of the bark, ſo far as they appear of any importance, will be diſcoverable from the following account of its various uſes in dying and calico-printing.

### *Of the Application of Quercitron Bark for the Dying of Wool and Woollen Cloths with an Aluminous Baſis.*

WOOL, and the cloths or ſtuffs made from it, ought, in all caſes, to be ſcoured before they are dyed, in order to ſeparate a kind of greaſe with which the fibres are naturally covered. This is uſually done by immerſing the wool or cloth for about a quarter of an hour in ſtale urine, diluted with three times as much water, and kept nearly of a ſcalding heat; it is afterwards to be thoroughly rinced in clean water, and then dyed without any previous drying, that the colour may apply itſelf more equally.

Alumine, or the earth of alum, precipitated by clean potaſh, and repeatedly waſhed in pure water, being boiled with Quercitron bark, readily united with its colouring matter, and produced a yellow inclining very much to the golden or, as it is called, the *yolkey* hue; and wool boiled in this mixture for the ſpace of half an hour, took a browniſh yellow, which, however, ſeemed to have been but ſuperficially applied, the earth of alum in its undiſſolved ſtate, not being able ſufficiently to enter the pores of the wool even when they are diſtended by boiling water.

The earth of alum diſſolved by the vegetable, the foſſil, and the volatile alkalies ſeparately, as well in their mild as in their cauſtic ſtates, was found to dye yellow colours of different ſhades, with the Quercitron bark upon wool; but they were all inferior to thoſe given by the ſame baſis (alumine) when diſſolved by acids.

The cheapeſt and moſt ſimple method of applying the Quercitron colour upon wool, is that of boiling up the bark with its weight or a third more than its weight of ſulphate of alumine (common alum) in a ſuitable portion of water for about ten minutes, and then dying therein the wool or cloth previouſly ſcoured as before mentioned, taking care to give the higher colours firſt, and the paler ſtraw colours afterwards. In this way yellows not wanted to be very full or bright may be dyed very expeditiouſly and cheaply; and they may afterwards be conſiderably raiſed and enlivened, by paſſing the wool or cloth unrinced a few times through hot water, into which a little clean powdered chalk has been previouſly ſtirred, in the proportion of about a pound or a pound and a half of chalk for each 100lb. weight of wool or cloth. The bark, when uſed in dying, (being first ground,) should always be tied up in a linen bag of a loose open texture, and suspended in the dying liquor by a cord, with which it may be dragged occasionally backwards and forwards through it, to extract and spread the colouring matter more equally.

But when the bark and alum are boiled together and united in this way, the colour does not afterwards fix itself either so readily, or so copiously upon the wool or cloth, as when the aluminous basis has been first applied separately in the common mode of preparation; and therefore this simple and cheap method of applying the Quercitron colour is only suited for straws and pale yellows, especially as there is reason to suspect, that the adjective colours of every kind are not so durable when dyed with an aluminous basis in this way, as when they are dyed upon a like basis previously conveyed into and fixed in the substance which is to be dyed.

As often, therefore, as any thing more than a pale yellow is intended to be given from the Quercitron bark and the aluminous basis upon wool or cloth, the latter should be boiled in the common way, but *without either tartar or argol*, for the space of an hour or an hour and a quarter, with about one sixth or one eighth of its weight of alum, dissolved in a suitable quantity of water, and then *without being rinced* it should be put into a dying vessel, with clean hot water, and about as many pounds of powdered bark, (tied up in a bag,) as there were used of alum to prepare the wool or cloth, which is then to be turned as usual by the winch through the boiling liquor, until the colour appears to have taken ſufficiently; and then about one pound of clean powdered chalk for every 100lb. of the wool or cloth, may be mixed with the dying liquor, and the operation continued eight or ten minutes longer, when the yellow will have become both higher and brighter by this addition of chalk.

The yellows given in this way from the Quercitron bark, are infinitely better and conſiderably cheaper than any which can be given from old fuſtic with an aluminous baſis: indeed they approach nearly to thoſe given by weld with the common preparation of alum and tartar, and are in every reſpect as durable; though it muſt be confeſſed, that they have leſs of that lively greeniſh or lemon hue, for which the weld yellows are particularly valued: this, however, may be readily and cheaply obtained in the *utmoſt perfection* from Quercitron bark, by means which will hereafter be explained.

Wool or cloth which has been firſt properly dyed blue in the common indigo vat, may be made to receive any of the various ſhades of green which are uſually given in this way from weld, by boiling the blue wool or cloth, (after it has been well rinced,) in water with about one eighth of its weight of alum, as juſt directed for producing a yellow, and afterwards dying it unrinced with about the ſame quantity of bark, and a little chalk, which ſhould be added towards the end of the proceſs, as already deſcribed. Greens of leſs body may be dyed with ſmaller portions of bark and alum.

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In the ſame way, cloth which has previouſly received the proper ſhade of Saxon blue, may be dyed of a beautiful Saxon green: it will be proper, however, for this purpoſe, that the blue cloth ſhould be firſt very well rinced to ſeparate, as far as water will do it, the acid which may have been imbibed from the ſulphate of indigo, and which has a ſtrong tendency to throw down and weaken the Quercitron as well as the weld yellows. But as mere rincing in water will ſeparate only a ſmall part of this acid from the cloth, (with which it combines in a certain degree,) it will be proper to add about three pounds of chalk, with ten or twelve pounds of alum, for the preparation liquor of 100lb. weight of cloth, which is to be turned and boiled as uſual for about an hour; and then, without changing the liquor, ten or twelve pounds of bark powdered and tied up in a bag, may be put into it, and the dying continued, taking care frequently to agitate the bag, in order that the colour of the bark may ſpread equally through the liquor. It will be found, however, that the yellow will manifeſt itſelf but ſlowly in this way by reaſon of the ſulphuric acid imbibed with the blue colour, joined to that of the alum in the preparation liquor, which the portion of chalk before mentioned will not have been ſufficient to overcome; and, therefore, when the dying with bark has continued about fifteen minutes, it will be proper to add another pound of clean powdered chalk, ſtirring it well through the liquor, and to repeat this addition afterwards once, twice, and even three times at intervals of ſix or eight minutes, if the colour does not riſe ſufficiently without it. By theſe additions, the Quercitron yellow will manifeſt and apply itſelf abundantly and equally, ſo as to produce very beautiful greens, which, by varying the proportions of indigo as well as of bark and alum, may be varied at pleaſure. The chalk, in this caſe, does not merely anſwer the purpoſe of decompoſing the acid left in the cloth by the ſulphate of indigo and the alum, but by uniting with this acid, it becomes a ſulphate of lime, and fixes itſelf, in part at leaſt, as a baſis in the fibres of the cloth, where it helps to raiſe the colour, and alſo to render it a little more durable. At preſent the Saxon greens are commonly dyed with the old fuſtic; becauſe the colour of this wood is not thrown down by acids ſo much as that of the bark and weld: and this difference enables the dyer, when he has extracted the fuſtic colour by previous boiling, to mix the ſulphate of indigo therewith, and dye the cloth green by one operation after it has been prepared as uſual with alum and tartar. The proceſs, however, which I have mentioned for doing this with bark, is full as cheap and as expeditious, and the green produced will be more beautiful, becauſe the Quercitron yellow is much more bright and clear than that of fuſtic.

At pages 210, 211, 212, and 213, I have deſcribed a method of combining the Pruſſian blue and the Quercitron yellow upon an aluminous baſis, ſo as to produce a green colour, which I had flattered myſelf might be advantageouſly employed upon wool: further trials, however, have manifeſted ſo much difficulty in applying the colour equally, that I have now but little expectation of its being ſucceſsfully employed in this way, and ſhall therefore ſay no more of it at preſent.

Durable yellows may alſo be dyed upon wool, with either the muriate, the nitrate, or the acetite of alumine, but not with any ſuperiority of colour which could compenſate for the increaſed expence of theſe aluminous preparations.

*Of the beſt Methods of dying upon Wool and Woollen Cloths with Quercitron Bark and the Tin Baſis.*

In the preceding chapter I have mentioned the different effects of ſome of the preparations of tin in exalting the colour of the Quercitron Bark, as well as that of cochineal; and it will be remembered, that *for this purpoſe,* I found the muriate and the murio ſulphate of tin, preferable to any other of the preparations of that metal; I obſerved, however, that the former of theſe had an injurious action upon the fibres of wool and cloth, unleſs when ſparingly and carefully employed, and was therefore leſs proper for general uſe than the ſolution of tin, made by a mixture of muriatic and ſulphuric acids, as deſcribed at page 290 of this volume; to which my readers will be now pleaſed to recur.

In order to dye 100lb. weight of cloth or woollen ſtuffs of the higheſt and moſt beautiful orange yellow, only 10lb. weight of Quercitron bark, and the ſame weight of murio ſulphate of tin, will be required; the bark powdered and tied up in a bag, may be firſt put into the dying veſſel with hot water, for the ſpace of ſix or eight minutes,

nutes, then the murio ſulphate of tin may be added, and the mixture well ſtirred for two or three minutes; after which the cloth, previouſly ſcoured and thoroughly wetted, may be put into the dying liquor and turned briſkly for a few minutes: the colour applies itſelf in this way, ſo equally to the cloth, and at the ſame time ſo quickly, that after the liquor begins to boil, the higheſt yellow may be produced in leſs than 15 minutes, without any danger of its proving uneven. High ſhades of yellow, ſomewhat approaching to thoſe dyed from bark in the way juſt mentioned, are frequently given with the rhus cotinus, (commonly, though improperly called young fuſtic,) and the dyers' ſpirit, or nitro muriate of tin; but the colour ſo given, is much leſs beautiful and more fugitive, as well as more expenſive, than that obtained from the bark as juſt deſcribed.

When a very bright golden yellow, approaching leſs to the orange, is wanted, ſeven or eight pounds of murio ſulphate of tin, with about five pounds of alum, and ten pounds of bark will ſuffice for 100lb. of cloth; the bark being firſt boiled a few minutes, then the murio ſulphate of tin, with the alum, added, and the cloth afterwards dyed as juſt directed. Pure bright yellows of leſs body, may be produced by employing ſmaller portions of bark, murio ſulphate of tin and alum, in the ſame way: and, indeed, all the poſſible ſhades of *pure bright yellow*, may be given with the utmoſt eaſe and certainty by only varying the proportions of theſe ingredients. But where it is expedient to give that *lively, delicate greeniſh tinge* which, for certain purpoſes is ſo much

much admired, and which the weld alone has been ſuppoſed capable of giving; white argol, or tartar, muſt be alſo employed with the bark, murio ſulphate of tin and alum, in different proportions, according to the particular ſhade intended to be given. Thus, e. g. for a full bright yellow, delicately inclining to the greeniſh tinge, it will be proper to employ about eight pounds of bark, and ſix pounds of murio ſulphate of tin, with ſix pounds of alum, and four of clean white tartar or cream of tartar; a little more alum and tartar will render the yellow more delicate, and give it more of the greeniſh tinge; and where this clean, lively, delicate greeniſh tinge is wanted in the greateſt poſſible perfection, it will be proper to uſe the bark, murio ſulphate of tin, alum and tartar all together in equal quantities. Theſe laſt delicately greeniſh lemon yellows, are but very ſeldom if ever wanted to be dyed of much fullneſs or body, and therefore ten pounds of bark, and the like quantities of murio ſulphate of tin, alum, and tartar, will generally prove ſufficient to dye three or four hundred pounds weight of cloth or woollen ſtuffs of the colours in queſtion; for which purpoſe the bark is to be firſt boiled a few minutes in water only, then the other ingredients are to be added, and mixed in the liquor by ſtirring and a few minutes boiling, and afterwards the cloth put into the liquor (firſt cooled a little) and turned briſkly through it until the colour appears ſufficiently raiſed. The pieces intended for the higheſt ſhades ſhould be always dyed firſt, and thoſe for weaker ſhades afterwards. When about two thirds of the whole quantity of cloth has been dyed, it will generally be found, that the liquor, by continuing to ex-

tract

tract colouring particles from the bark, has acquired an over proportion of the latter, and wants a ſmall addition of murio ſulphate of tin, alum, and tartar, (perhaps a pound of each,) to enable it to give the ſame delicately pale, though lively greeniſh tinge as at firſt: and indeed a ſurer way of giving theſe very pale greeniſh ſhades with exquiſite delicacy and beauty, is to boil the bark with a ſmall proportion of water in a ſeparate tin veſſel for the ſpace of ſix or eight minutes, then add the murio ſulphate of tin, alum, and tartar, and boil them all together for about fifteen minutes, and afterwards put a little of this yellow liquor into a dying veſſel, previouſly ſupplied with water ſufficiently heated, and the mixture being properly ſtirred, to begin dying the cloth as uſual, adding farther ſupplies of the yellow liquor from the firſt veſſel, by a little at a time, as faſt as it may be wanted. In this way the paleſt and moſt delicate ſhades may always be dyed with eaſe and certainty; and thoſe who have never ſeen the effects of this proceſs, will hardly conceive the exquiſite beauty and delicacy of theſe pale, but lively greeniſh lemon yellows, which certainly coſt leſs than any ſimilar colours given, if ſuch can be given, by any other means. Weld is unqueſtionably the only dying ware capable of producing effects ſimilar to thoſe of the bark in this reſpect, and at the average price it will prove nearly four times as coſtly, regard being had to the ſmaller portion of colour which it affords, beſides the expence of long boiling, which the bark does not want, to extract its colour. Indeed it may generally be computed, that the yellows dyed from Quercitron bark, with murio ſulphate of tin and alum, do not coſt in

dying

dying materials, more than one penny for each pound of cloth, and that in time, labour, and fuel, they do not coſt half as much as thoſe uſually given by other means. And this is alſo true of the more delicate ſhades given by bark, murio ſulphate of tin, alum, and *tartar*; for though this laſt ingredient be expenſive, it is wanted only for the paler colours, which require ſmaller portions of dying materials, and therefore do not coſt more than the higheſt ſhades given without it.

A greeniſh tinge may, indeed, be produced without tartar, by employing in its ſtead a little verdigriſe diſſolved by vinegar along with the bark, &c. but I think it is neither ſo laſting, nor ſo delicately clean and beautiful as that produced by the uſe of tartar. The ſulphate of indigo will alſo produce this greeniſh tinge if employed in a very ſmall quantity with the bark, murio ſulphate of tin, and alum; but it has a tendency to fix itſelf ſo quickly upon the fibres of wool or cloth, that great care is neceſſary to hinder it from taking unequally, and the tinge produced by it is, moreover, ſomewhat liable to caſt or fly, as the dyers ſay, in the finiſhing part; whilſt the greeniſh tinge reſulting from the uſe of tartar as before directed, will leave the preſs perfectly clear and bright. Indeed the colours obtained from Quercitron bark by theſe means, are very durable; they withſtand even the action of ſtrong mineral acids and of boiling ſoap ſuds, as well as expoſure to air. This laſt, indeed, they are principally enabled to reſiſt by the good effects of alum, and more eſpecially of tartar. Since the higheſt yellows, which approach very nearly to the

the orange, and which are beſt dyed either with muriate, or murio ſulphate of tin and bark, though they bear the action of ſoap and of acids in a wonderful degree, are liable after ſome time to looſe a conſiderable part of their luſtre, and acquire a browniſh complection by expoſure to the ſun and air. This is alſo true of yellows dyed with nitro muriate of tin (dyer's ſpirit) as a mordant, not only when employed with the bark, but with weld, and in a greater degree with fuſtic and other yellow vegetable colouring matters. In ſome of which this defect is not ſo well obviated by alum and tartar, as it is in the Quercitron and weld yellows.

I muſt here remark, that tin, by whatever means diſſolved, when applyed as a baſis for dying wool, renders the fibres a little harſh; ſo that they neither run ſo far nor ſo eaſily in ſpinning as they would otherwiſe do, and the wool itſelf is apt to appear coarſer; which is one reaſon for not dying ſcarlet in the fleece, and it may be one for not dying wool yellow with any of the ſolutions of tin as mordants, until it has been woven, or at leaſt ſpun; though I am perſuaded this defect is in a great degree obviated by employing the murio ſulphate of tin, with a mixture of alum, or of alum and tartar, and combining theſe with the colouring particles of the bark, (in the ways which I have deſcribed,) *before* they are applied to the wool or cloth.

When yellows not quite ſo lively and beautiful can be made to anſwer, a much ſmaller proportion of the ſulphate of tin will prove ſufficient; five pounds thereof, for inſtance, may be boiled with

with ten pounds of bark, ten pounds of alum, and two or three of tartar, and the cloth dyed as before directed. The decompoſition and recompoſition which reſult from a mixture of tartar with murio ſulphate of tin, will be readily conceived from what has been mentioned on this ſubject in the preceding chapter.

By uſing very ſmall proportions of cochineal with the bark, murio ſulphate of tin, &c. the colour may be raiſed to a beautiful orange, and even to an aurora. Madder alſo employed in this way, raiſes the Quercitron yellow, but the effect is leſs beautiful than with cochineal; and this is alſo the caſe when madder is employed with weld.

At pages 189 and 190, I have made ſome mention of the means of dying woollen cloth topically or partially, and ſince that time I have found, that by mixing a ſtrong decoction of the bark, with a ſuitable proportion of murio ſulphate of tin, &c. and thickening the mixture, as for the profubſtantive topical yellows hereafter to be deſcribed for calico-printing, then applying the mixture by a pencil to the woollen cloth, covering the pencilled parts with paper, ſo as to prevent the moiſt colour from ſpotting the other parts, afterwards folding up the cloth and tying it in a bag made of that kind of oiled linen which is uſed for bathing caps, ſo as to exclude water, and then keeping it immerſed in boiling water for a quarter of an hour, a full and beautiful yellow was fixed upon the parts which had been pencilled, without any farther running or ſpreading of the colour. The ſame mixture pencilled upon cloth which

which had been previoufly dyed Saxon blue, produced a beautiful green where it had been pencilled. Diluted fulphate of indigo pencilled upon fcarlet cloth and treated in the fame way, produced a full black; and it feems to be eafy, by employing proper mixtures in this way, to produce all the varieties of colours topically upon woollen ftuffs: as far as I can judge, the oiled linen, which I believe was never before employed for this purpofe, is much more fuitable to it than the means now in ufe.

The moft beautiful Saxon greens may be produced very cheaply and expeditioufly by combining the lively yellow which refults from Quercitron bark, murio fulphate of tin, and alum, with the blue afforded by indigo when diffolved in fulphuric acid, as for dying the Saxon blue.

To produce this combination moft advantageoufly, the dyer, for a full bodied green, fhould put into the dying veffel after the rate of fix or eight pounds of powdered bark (in a bag) for every 100lb. weight of cloth, with only a fmall proportion of water as foon as it begins to grow warm; and when it begins to boil, he fhould add about fix pounds of murio fulphate of tin, (with the ufual precautions,) and a few minutes after, about four pounds of alum; thefe having boiled together five or fix minutes, cold water fhould be added, and the fire diminifhed fo as to bring the heat of the liquor nearly down to what the hand is able to bear; and immediately after this, as much fulphate of indigo is to be added as will fuffice to produce the fhade of green intended to be dyed, taking care to mix it thoroughly with the by ſtirring, &c.; and this being done, the cloth previouſly ſcoured and moiſtened, ſhould be expeditiouſly put into the liquor, and turned very briſkly through it for a quarter of an hour, in order that the colour may apply itſelf equally to every part, which it will certainly do in this way with proper care. By theſe means, very full, even, and beautiful greens may generally be dyed in half an hour; and during this ſpace, it is beſt to keep the liquor at rather leſs than a boiling heat. Murio-ſulphate of tin, is infinitely preferable, for this uſe, to the dyer's ſpirit; becauſe the latter conſiſts chiefly of nitric acid, which by its highly injurious action upon indigo, would render that part of the green colour very fugitive, as I have found by repeated trials. But no ſuch effect can reſult from the murio-ſulphate of tin; ſince the muriatic acid has no action upon indigo, and the ſulphuric is that very acid which alone is proper to diſſolve it for this uſe.

Reſpecting the beauty of the colour thus produced, thoſe who are acquainted with the unequalled luſtre and brightneſs of the Quercitron yellows, dyed with the tin baſis, muſt neceſſarily conclude, that the greens compoſed therewith will prove infinitely ſuperior to any which can reſult from the dull muddy yellow of old fuſtic: and in point of expence, it is certain that the bark, murio-ſulphate of tin, and alum, neceſſary to dye a given quantity of cloth in this way, will coſt leſs than the much greater quantity (ſix or eight times more) of fuſtic, with the alum neceſſary for dying it in the common way; the ſulphate of indigo being the ſame in both

 caſes.

cafes. But in dying with the bark, the veffel is only to be filled and heated once; and the cloth, without any previous preparation, may be completely dyed in half an hour; whilft in the common way of producing Saxon greens, the copper is to be twice filled; and to this muft be joined the fuel and labour of an hour and an half's boiling and turning the cloth, in the courfe of preparation, befides nearly as much boiling in another veffel to extract the colour of the fuftic, and after all, the dying procefs remains to be performed; which will be equal in time and trouble to the whole of the procefs for producing a Saxon green with the bark; fo that this colour obtained from bark will not only prove fuperior in beauty, but in cheapnefs, to that dyed as ufual with old fuftic.

Mr. Dambournay, in the fupplement to his "Recueil de procedés & experiences fur les teitures folides," &c. mentions various experiments made by him with the Quercitron bark, from which he concludes, that in order to produce the good effects which I had previoufly defcribed as refulting from its ufe in dying woollen cloths, thefe fhould be firft impregnated with a tin bafis, and then dyed in the manner which I had directed. In this way, fays he, I obtained full fhades of that beautiful yellow, a little greenifh, but very durable, ("de cé "beau jaune un peu verdatre & tres folide,") which is fo well fuited to produce a *fine green*, either by the indigo vat, or by the compofition for Saxon blue, i. e. fulphate of indigo. And having applied this latter by the common mode of dying, to cloth which had previoufly received the

the Quercitron yellow, and alſo to cloth dyed yellow with the Lombardy poplar, (which in other reſpects he greatly commends,) he found that the former which had received the bark yellow, took a fine dragon green, (" un beau " vert dragon,") and the latter nothing better than a greeniſh olive. It is true that Mr. Dambournay computes the expence of dying with the Quercitron bark as greatly ſurpaſſing that of dying with the Lombardy poplar. But his computation was founded on very erroneous ſuppoſitions, joined to the circumſtance of his calculating the muriatic acid to coſt near two ſhillings and ſixpence ſterling the pound weight, which is more than ſix times its real coſt; tho' this may probably have been nearly the price which it bore in France, whilſt the *Gabelle* ſubſiſted there.

The nitro muriate of tin, (dyer's ſpirit,) tho' it produces good yellows with Quercitron bark, produces them in a much weaker degree than the murio ſulphate of that metal; which is really the cheapeſt, and moſt efficacious, of all the ſolutions or preparations of tin, for dying the Quercitron as well as the cochineal colours.

The ſulphuric acid by itſelf diſſolves, or rather calcines, a large portion of tin, if allowed to act upon it for any conſiderable time; and this ſolution joined to the bark, with alum and tartar, produces bright ſtrong yellows on cloth, though I think they appear leſs ſoft and beautiful, than thoſe dyed either with the muriate, or murio ſulphate of tin. This metal diſſolved, or rather calcined, by a mixture of the nitric and ſulphuric acids, is ſtill leſs ſuitable for dying with the bark.

Tin diſſolved by muriatic acid, to which one third of its weight of clean white tartar had been previouſly added, produced a very bright and delicate yellow with the bark, upon cloth, and this, by longer boiling, was raiſed to a full and beautiful orange. Tin diſſolved in ſtrong nitric acid, (double aqua fortis,) with an addition of one third of its weight of tartar, alſo produced a very good yellow, though ſomewhat inferior to the laſt.

Upon putting tartar, with a portion of tin, into a glaſs veſſel with ſtrong colourleſs ſulphuric acid, the latter, or rather its oxygenous part, by combining with the inflammable part of the tartar, immediately rendered the mixture as black as ink; and the ſolution of tin produced by it, was found of but very little uſe as a mordant for dying with the bark.

A ſolution of tin, by the oxygenated muriatic acid, whilſt ſecluded from light, retains its oxygenous part, and with it the power of weakening a great number of adjective colours; a power which depends neither upon the oxygene, nor the muriatic acid ſeparately, but upon the new properties which they acquire by combination. The oxyd of tin, produced by the action of the nitric acid upon that metal, contains a large portion of oxygene; and yet it raiſes, inſtead of weakening the Quercitron yellow: but when this oxyd is diſſolved in muriatic acid, it produces only a very feeble lifeleſs yellow

yellow with bark; though tin not previoufly oxygenated will, when diffolved by the fame (muriatic) acid, act moft powerfully in exalting the Quercitron yellow: which proves, that this defect of colour does not refult from the prefence of oxygene alone, but from its combination with muriatic acid. The defect in this cafe is exactly fimilar to that which occurs when tin, diffolved by oxygenated muriatic acid, is employed with the bark; and in both cafes, the very feeble yellows produced, refemble that which I have defcribed in the laft chapter, as refulting from the ufe of tin, diffolved by muriatic acid, oxygenated by the addition of about one third of its weight of nitric acid: a fimilar effect was alfo produced by employing tin calcined by fulphuric acid, and then diffolved in the muriatic, as a mordant with the bark.

Cloth boiled in water with the muriate of tin and tartar, has fometimes been made yellow, and fometimes of a chefnut brown, *only* from the action of this mordant, unaffifted by any colouring drug. Thefe difcolorations feem to depend upon the particular ftate of the cloth, as being more or lefs freed, either from the natural fwint of the wool, or the greafe commonly applied to it for particular purpofes. Difcolorations of this kind are not eafily removed; they withftand the action of fun and air for a confiderable time, and if cloth fo difcoloured be dyed with either bark, or with cochineal, the colour will appear tarnifhed; for which reafon the application of muriate of tin, with tartar *only*, as a mordant, ought to be avoided, unlefs the dyer be very

 certain

certain that the cloth has previouſly been perfectly well ſcoured.

A few lumps of the dry oxyd of tin mentioned at page 118, having been finely powdered and mixed with a ſuitable quantity of decoction of Quercitron bark, the mixture was found capable of dying a very full and bright yellow upon woollen cloth. The colour however being expoſed to the action of ſun and air, very ſoon acquired a browniſh complexion. Some of the ſame oxyd of tin reduced to powder, having been waſhed in warm water, to remove the adhering acid, as far as water could remove it, was found to be ſtill capable of combining with the colouring matter of the bark, ſo as to dye cloth yellow; eſpecially when the oxyd had been previouſly ſuffered to remain mixed with the decoction of bark, for ſome hours, in a warm ſituation. Cotton alſo took a yellow colour by dying in this mixture; but it was eaſily removed by waſhing with ſoap, and therefore was I think only applied ſuperficially.

I have but little to offer reſpecting the uſe of copper, or rather of the oxyd and ſolutions of that metal *alone*, as mordants or baſes for dying with Quercitron bark on wool or cloth. Their general effect is to raiſe and fix the Quercitron yellow; but at the ſame time to give it a greeniſh or rather an olive complection. Wool dyed with a tenth of its weight of bark, and half as much ſulphate of copper, received an agreeable colour, between the yellow and the olive. The bark, with muriate of copper, ſeemed to impart but little colour to wool for ſome time; but a

little

little chalk being added, a full yellowiſh olive was produced. This alſo proved to be the caſe, when nitrate of copper was employed with the bark, until chalk had been added; and then the wool ſpeedily imbibed a yellow, delicately inclining to the olive hue. Verdigriſe with the bark produced a yellowiſh olive on wool; which, by the addition of chalk, was brightened, and made to approach nearer to the yellow. Theſe colours appeared to be ſufficiently laſting.

*Drab colours* of various ſhades may be moſt expeditiouſly and cheaply dyed by the Quercitron bark, and an iron baſis. For this purpoſe the bark may be boiled a few minutes in a copper veſſel, with one half, one third, or one fourth of its weight of ſulphate of iron, (copperas,) according to the ſhade required, and the liquor having been well mixed, and a little cooled, the cloth may be dyed therein as uſual; but without any other preparation than that of ſcouring and moiſtening. To ſadden and darken the colour ſtill farther, a little ſumach, (rhus coriaria,) may be added with the bark; and on the other hand, the colour may be inclined to the olive and yellow, by diminiſhing the quantity of ſulphate of iron, and employing with it a little alúm and chalk; or (which is better) a little ſulphate of copper, with or without a ſmall proportion of chalk. Or the cloth may be firſt turned a few times through a veſſel, with boiling bark liquor, then taken out, and turned briſkly through a veſſel with hot water, in which a ſuitable proportion of ſulphate of iron has been diſſolved, with or without either alum and chalk, or ſulphate of copper and chalk, as the particular colour intended to be given may require. In either way the colours will prove lafting, and the expence very fmall; four or five pounds of bark being generally fufficient to dye one hundred pounds weight of cloth, of the colours in queftion. Cloth prepared by previous boiling, with one twentieth of its weight of fulphate of iron, and one fourth of that quantity of chalk, and then dyed in bark liquor, became of a ftrong durable chocolate colour; but in this way great care is neceffary to render the colour even.

Cloth prepared by boiling with a twentieth of its weight of fulphate of iron, half as much fea falt, and one fourth of that quantity of chalk, and then dyed with bark, received a very lafting dark brown colour.

Cloth dyed with Quercitron bark, fulphate of iron, and fulphate of manganefe, in fmall proportions, became of a light but pleafing drab colour; which, by the addition of a little chalk, was afterwards changed to the cinnamon.

Cloth prepared with nitro muriate of gold, and dyed with bark, became of a delicate olive tinged yellow. The folutions of bifmuth, zinc, antimony, filver, mercury, lead, and platina, by different acids, produced various fhades of brown, yellowifh brown, brownifh yellow, cinnamon, drab and olive colours; of which it is not expedient to give my readers a particular defcription; becaufe they either may be all more cheaply obtained by other mordants, or are not likely to be brought into ufe.

Cloth

Cloth boiled in water, with one twentieth of its weight of ſulphate of lime, and dyed with Bark, received a ſtrong nankeen colour. Nitrate of lime in this way, produced a nutmeg brown; and the muriate of lime produced a very full and laſting drab colour, which in ſome reſpects may be preferable to the drabs given by an iron baſis, and eſpecially as being leſs likely than the latter to injure the texture of the cloth.

*Of the Properties and Uſes of Quercitron Bark in dying upon Silk.*

ALL the different ſhades of yellow, commonly dyed upon ſilk from weld, may be obtained with equal facility and beauty, and more cheaply, by employing the bark in its ſtead, after the rate of from one to two pounds for every twelve pounds of ſilk, according to the particular ſhade of colour wanted. For this purpoſe the bark, powdered and tied up in a bag, ſhould be put into the dying veſſel whilſt the water is cold, and as ſoon as it becomes a little more than blood warm, the ſilk, previouſly alumed, ſhould alſo be put in and dyed as uſual; and where the higher yellows are wanted, a little chalk or pearl aſhes may be added towards the end of the operation, as mentioned for the dying of wool.

Where ſhades of yellow more lively than any which can be given either by weld or bark with the aluminous baſis only, are wanted, it will be advantageous to employ a little of the murio ſulphate of tin; and but a little of it, becauſe the calx of tin, unlefs fparingly ufed, always diminifhes the gloffinefs of filk.

To produce the fhades in queftion, it will be fufficient to boil after the rate of four pounds of bark, with three pounds of alum and two pounds of murio fulphate of tin, with a fuitable quantity of water, for ten or fifteen minutes, and the heat of the liquor being afterwards reduced fo that the hand can bear it, the filk is to be put in and dyed as ufual, until it has acquired the proper fhade, (which it will do fpeedily,) taking care, however, to agitate the liquor conftantly, that the colouring matter, which would otherwife fubfide in a confiderable degree, may be kept equally difperfed through the liquor. By adding fuitable proportions of fulphate of indigo to this yellow liquor and keeping it well ftirred, various and beautiful fhades of Saxon green may be dyed in the fame way very equally and cheaply. The Shades intended to incline moft to the yellow fhould be firft dyed, and afterwards, by adding more fulphate of indigo, thofe partaking more of the blue may be readily produced; and indeed nothing can be more commodious or certain than this way of dying the moft beautiful Saxon greens upon filk.

By diffolving different proportions of copperas or copperas and alum, in the warm decoction of bark, filk may in the fame way be dyed of all the different fhades of olive and drab colours; and other varieties may be produced with the bark generally, by employing the fame means which are ufed to produce the like variations with weld.

*Of the Application of Quercitron Bark to the Fibres of Linen or Cotton, either woven or ſpun, by general Dying.*

I here uſe the term *general* dying as oppoſed to that *partial* or *topical* application of colours on which callico-printing chiefly depends. At pages 62 and 63 of this volume I have endeavoured to explain the cauſes which render adjective colours leſs durable on linen and cotton than they are on wool or ſilk, ſo far, at leaſt, as theſe cauſes depend on differences in the ſtructure and chymical properties of the ſubſtances in queſtion; but whether my explanation be well founded or not, this at leaſt is certain, that the attraction between the aluminous baſis, and the fibres of linen and cotton is much weaker than that which ſubſiſts between the ſame baſis, and the fibres of wool or of ſilk; and this want of a ſufficient attraction or affinity has made it neceſſary to employ extrordinary means for precipitating the alumine more copiouſly, and fixing it more firmly than it otherwiſe would be precipitated and fixed upon the fibres of linen or cotton, in order to enable them to receive permanent adjective colours by dying. The principal of theſe means are certain oily and animal matters joined to ſome vegetable aſtringents, particularly galls; all of which, I mean the former, as well as the latter, evidently poſſeſs a ſtrong attraction for alumine, and when united to linen or cotton, produce very beneficial effects, as is manifeſtly ſeen by the proceſs for dying the Adrianople or Turkey red, concerning which both Mr. Henry and Mr. Berthollet

Berthollet have publiſhed ſeveral very ingenious as well as highly intereſting obſervations; and perhaps I may be able to add ſomething to theſe when treating of this ſubject in my next volume; at preſent, however, I ſhall only notice theſe extraordinary means ſo far as they ſeem likely to improve the beauty and durability of the colours, capable of being communicated to linen or cotton from Quercitron bark.

The fibres of linen or cotton when ſpun or woven are prepared for the dyer by being firſt boiled in water with a ſuitable portion of potaſh, (which for linen ſhould be made cauſtic, in order that it may act more ſtrongly upon the oily and reſinous matters abounding in flax,) and afterwards bleached by expoſure upon the graſs to ſun and air. But as this operation commonly leaves a portion of earthy matter in the linen or cotton, which, by being unequally diſtributed, would render any colour given by dying unequal; the cotton or linen ought to be ſoaked or ſteeped in water, ſoured by ſulphuric acid, to diſſolve and remove this earthy matter, taking care afterwards to waſh or rince off the acid, leſt, being concentrated in the cloth or yarn when drying, it ſhould injure the texture.

The method preſcribed by the French regulations, and adopted in moſt European countries, for dying yellow upon linen or cotton from the weld plant is, by ſoaking the cloth or yarn in a liquor made by diſſolving one-fourth of its weight of alum in as much water as is neceſſary for that purpoſe; to which it will be highly advantageous to add after the rate of one pound of clean potaſh, or ten ounces of chalk, for every ſix or ſeven pounds of alum (1) to neutralize the exceſs of acid contained in the alum, and promote a ſeparation of its earthy baſis. The cloth or yarn having been thus ſoaked, is taken out of the alum liquor, and well dried; and being afterwards rinced, it is to be dyed in weld liquor made by boiling about one pound and a quarter of the plant for each pound of cloth or yarn; which, after having received a ſufficient body of colour, is to be taken out of the dying liquor, and ſoaked for an hour and more in a ſolution of ſulphate of copper (blue vitriol) containing after the rate of three or four ounces of the latter for each pound of cloth or yarn; it is then to be removed, and without being waſhed, put into a boiling ſolution of hard ſoap, containing in like manner three or four ounces of ſoap for each pound of cloth or yarn, in which it is to be well ſtirred and boiled for about three quarters of an hour or more, then waſhed and dryed. I have found by repeated trials that this mode of precipitating the calx of copper upon the yellow previouſly dyed from weld with an aluminous baſis, renders the colour more durable, but at the ſame time gives it a darker complexion. And I have found ſimilar effects where bark was uſed inſtead of weld; the colour dyed with the bark in this way having proved in every reſpect as good as that obtained from

(1) Hauffman ſays, that when Engliſh alum is diſſolved in five times its weight of water, and one eighth of its weight of chalk is added to ſaturate the exceſs of acid, a ſolution will be produced which does not cryſtalize in Summer, and but little in Winter; though without chalk it requires ſixteen times as much water as of alum to make a permanent ſolution.

from weld: but I am convinced, that whether the colouring matter be taken from the former or the latter of theſe vegetables, the yellow dyed in this way never is either ſo beautiful or ſo laſting as that partially given by callico-printers from the ſame vegetables, and which the dyers might readily give with equal perfection, by only employing the acetite of alumine, or aluminous mordant, deſcribed at pages 176, 177, and 178 of this volume; and this more cheaply as well as more expeditiouſly than that produced by following the French regulations; conſidering the expence of ſo much blue vitriol and ſoap as they require, and which may be rendered unneceſſary by adopting the calico-printer's aluminous mordant.

The beſt method of applying the aluminous mordant for general dying with Quercitron bark (which I moſt earneſtly recommend whenever bright and durable yellows are wanted,) is as follows, *viz.*

Take a ſufficient quantity of the acetite of alumine, which for this purpoſe may be made by diſſolving after the rate of *only* one pound of ſugar of lead and three pounds of alum, as at page 177, excepting only that it need not be thickened, and mix this liquor with an equal quantity of warm water, then let the linen or cotton (properly cleanſed as before mentioned) be thoroughly wetted and ſoaked in the mixture, which ought to be about blood warm, for the ſpace of two hours, then taken out and moderately preſſed or ſqueezed over a proper veſſel to collect what might otherwiſe drop or run off, and prevent an unneceſſary waſte of the aluminous liquor; and

this

this being done, let the linen or cotton be well dried in a ſtove heat, where it can be conveniently applied, and then ſoaked again in the aluminous mordant, and again preſſed or ſqueezed and dried as before; after which, without having been rinced, let it be thoroughly wetted in as much, and only as much lime water as will conveniently ſuffice for that purpoſe, and afterwards dried; and where a very full, bright, and durable yellow is wanted, it may be well to ſoak the linen or cotton a third time in the diluted aluminous mordant, and after drying, wet it a ſecond time with lime water, and dry it again: but in either caſe, the linen or cotton after its laſt dying, ſhould be well rinced in clean water, in order to ſeparate any looſe or unfixed particles of the mordant or baſis, which otherwiſe might do harm in the dying veſſel. The lime-water employed in this way, anſwers the purpoſe of producing a more copious depoſition of the alumine in the fibres of the linen or cotton, and it moreover ſuperadds a portion of calcarious to the aluminous baſis; an effect which is not without conſiderable utility.

I have found, that when the aluminous liquor has been employed at a ſcalding heat, the colour afterwards produced was not ſo good as what reſults from liquor only made blood warm; the pores of linen and cotton being ſo open as not to require any diſtenſion by a greater degree of heat.

The cotton or linen being prepared and rinced as before mentioned, a ſmall fire is to be lighted under the dying pan or veſſel, previouſly ſupplied with the uſual quantity of water, and the pow-

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dered Quercitron bark tied up in a bag, after the rate of from twelve to eighteen pounds for every hundred pounds weight of linen or cotton where full bodied yellows are wanted, is to be put in, whilſt the water is cold, and immediately after it the linen or cotton is alſo to be put in, upon ſticks if it be thread or yarn, or, if piece-work, on the winch, agitating or turning it in either caſe as uſual for the ſpace of an hour or an hour and a half, during which the water ſhould gradually become warm, but not warmer than the hand can bear. When this time has elapſed, the fire may be increaſed, and the dying liquor brought to a ſcalding and thence to a boiling heat; in which it will be ſufficient to let the cotton or linen remain a few minutes only, when a bright lively yellow is wanted, becauſe longer boiling always gives the yellow a browniſh caſt, whatever vegetable may be employed in dying it. The linen or cotton having thus acquired ſufficient colour, is to be taken out, rinced and dried as uſual.

When the colour of Quercitron bark is ſlowly raiſed in this manner by a very moderate heat, the colouring particles ſeem to adjuſt themſelves more accurately and unite more intimately to thoſe of the baſis, and thereby to produce a colour more fixed and durable than it is when they are haſtily accumulated by a boiling heat, and perhaps chiefly upon the ſurface of the ſubſtance dyed and of the baſis combined therewith.

All the different ſhades of yellow may in this way be dyed from Quercitron bark; if it be uſed ſparingly, with a very moderate heat, and the operation

operation continued only for about half an hour, a pale though lively yellow will refult; if ufed more copioufly, and the operation continued fomewhat longer, a fuller colour will be produced; and this may be raifed higher and higher according as the heat and proportion of bark are increafed and the dying operation prolonged, fo as indeed to produce a very dark brownifh yellow if the liquor be made to boil for half an hour.

Pieces of cotton having been prepared with the printers' aluminous mordant and lime water, as already defcribed, were dyed one with bark and another with weld, and being taken out of the dying liquors, a bit was cut off from each and the remainder put back again into its liquor, in which a fmall quantity of fulphate of copper had, in the mean time, been diffolved, after the rate of one ounce to five pounds of cotton; and the liquors being nearly of a fcalding heat, in about ten minutes the pieces were again taken out and found to have acquired a brownifh complexion; but being expofed to the fun and air along with the bits which had been cut off before the fulphate of copper was added to the dying liquors, the brownifh complexion of the former foon difappeared, and their remaining colour at the end of four weeks proved to be rather better than that of the bits dyed without the fulphate of copper. It feems therefore probable, that a fparing ufe of the latter in this way, may contribute fomething at leaft to the durability, if not to the beauty of yellows dyed upon linen or cotton, *after* the application of acetite of alumine and of lime as before directed.

When the aluminous mordant is employed without any addition of water, it may be ſuffi-cient to ſoak the cotton therein *once* only, and after dying to immerſe it *once* in lime water, then dry, rince, and dye it as before mentioned. I think, however, that better effects reſult from the application of a more diluted mordant, *at two different times*; and indeed I have found, that by immerſing the cotton *a greater number of times* alternately in the diluted aluminous mordant and in lime water, and drying it after each immerſion, the colour always acquired ſtill more body and durability.

At page 183 I have remarked, that by the Eaſt Indian method of callico-printing, the want of acetile of alumine is ſupplied by impregnating cotton with the aſtringent matter of yellow my-robalans, and with certain oily and animal ſub-ſtances, which enable the cotton, when a ſolu-tion of alum is afterwards applyed to it, to de-compoſe and imbibe a larger portion of alumine: and this practice may be imitated in dying the Quercitron yellow upon cotton, with ſo much advantage as to render the acetile of alumine in a great degree unneceſſary, at leaſt where the yellow is not required to be very clear and bright.

Inſtead of myrobalans, (which are, however, to be found here,) the Alleppo galls may be em-ployed, chooſing always the whiteſt for this uſe, becauſe the browner might ſtain the cotton, ſo as to render it incapable afterwards of receiving a bright, clear yellow; and perhaps in this reſpect the roots of at leaſt two or three ſpecies of North

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American ſumach, particularly the Rhus Glabra Lin. might be preferable even to the whiteſt galls, by communicating leſs ſtain and producing equally good effects, as I have found them to do in repeated trials.

The beſt method of employing galls for this purpoſe is, I believe, to boil after the rate of one pound of them coarſely powdered, with half a pound of Barilla, for the ſpace of one hour, in two or three gallons of ſoft water, and then ſtraining off the decoction to macerate the cotton an hour or two therein: barilla, or rather the ſoda which it contains, enables the water to extract the aſtringent matter of the galls much more copiouſly than it otherwiſe could do; and being itſelf imbibed by the cotton, it alſo occaſions a more plentiful depoſition of alumine, when the cotton is afterwards put into a ſolution of alum, which, for this uſe may be made by diſſolving eight pounds of alum and one pound of chalk in ſix gallons of water. In this calcarious ſolution of alum, the cotton, after being taken out of the decoction of galls and dried, is to be ſoaked for two hours, then taken out and dried; then ſoaked a few minutes in lime water, and having been again dried, it is to be immerſed a ſecond time in the calcarious ſolution of alum; after which, being again dried and well rinced, the cotton is to be dyed ſlowly with the Quercitron bark, as before directed. In this way very full bodied and laſting yellows may be obtained, which will bear repeated waſhings with ſoap, as well as expoſure to ſun and air; and the action not only of ſtrong vinegar, but of the oxygenated muriatic acid.

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By diſſolving after the rate of one pound of hard white ſoap and half a pound of barilla in three gallons of water, and macerating the cotton therein, as directed to be done with the decoction of galls and ſumach, then drying and immerſing it in the calcarious ſolution of alum, and afterwards proceeding, as juſt directed to be done after ſuch immerſion, I obtained a colour (with the bark) nearly as durable as when the decoction of galls had been uſed, and with the advantage of its not being thereby *darkened.*

A pound of the yolks and whites of eggs having been firſt beat up with an equal quantity of brown ſugar, and then with two gallons of water, and cotton having been ſoaked therein, inſtead of the ſolution of ſoap and barilla, then dryed and immerſed in the calcarious ſolution of alum; dried again and immerſed in lime water, and then in the ſolution of alum, and afterwards rinced and dyed with bark, as already deſcribed, it received a very full and laſting though darkiſh yellow colour. The animal mucilages in general, and ſome of the vegetable, being diſſolved in water and applied to cotton in the ſame way as the yolks and whites of eggs juſt mentioned, produce the like good effects, and more eſpecially the animal glues, which appear to unite both with the cotton and the aluminous baſis when uſed in this way.

A conſiderable time has now elapſed ſince I was induced to try the effects of alumine combined with other acids beſides the ſulphuric and acetous, and alſo with potaſh, ſoda and ammoniac, both in their mild and their cauſtic ſtates, as a baſis or mordant for the Quercitron colouring matter.

matter. To ſeparate alumine from the ſulphuric acid with which it forms common alum, this laſt compound may be diſſolved in about eight times its weight of clean boiling water, and mixed with a filtered lixivium of clean potaſh, which ſhould be added to the ſolution of alum gradually, until it no longer makes the liquor turbid, or occaſions any farther precipitation of alumine. The whole of the mixture may then be put into a canvaſs ſtrainer to ſeparate the fluid part, and this having been done, boiling water may be poured repeatedly upon the remaining moiſt alumine, and ſuffered to run through the ſtrainer until the ſaline part of the mixture ſhall have been waſhed away, as far as it is capable of being waſhed away by water; the alumine being then taken out and dried, will generally be found to weigh about one fifth part of the weight of the alum employed to produce it: when thoroughly dried, the alumine contracts or ſhrinks greatly, and becomes at length ſo hard, that neither ſtrong ſulphuric or nitric acids can diſſolve it, except with great difficulty and very ſlowly; and for this reaſon it ought always to be employed in a moiſt ſtate when intended to be again diſſolved by any acid or alkaline menſtruum. Perhaps the great diſpoſition of this earth to contract or ſhrink by drying, may be one reaſon why it is generally moſt advantageous to convey and fix the particles thereof as a baſis in the pores of linen or cotton, *firſt* ſeparately, and afterwards when they have ſhrunk by drying, to ſuperadd the adjective colouring matter, which may then find more ſpace, and combine with the alumine in greater proportion than it could do when both previouſly united, were applied together, whilſt the particles of alumine were enlarged by moiſture.

If moist alumine obtained in the manner just described, be dissolved in either the nitric or muriatic acids, it will by evaporation afford crystals; and those obtained with the nitric acid, by attracting moisture from the atmosphere, will prove deliquescent, unless kept in a vessel closely stopped. M. Berthollet found, that in these cases, the crystals depended on a remnant of sulphuric acid, which always adheres to alumine when separated in the way just described; and that by afterwards digesting it for some time in a solution of potash, or of ammoniac, this adhering sulphuric acid might be decomposed; and that the alumine being then dissolved either in the nitric or the muriatic acid, no crystals were produced. It must, however, be remarked, that the alumine mentioned to have been employed in the succeeding trials, was obtained in the way first described, and therefore was not completely divested of sulphuric acid.

Having boiled a suitable portion of moist alumine with a decoction of Quercitron bark during the space of half an hour, I attempted to dye both wool and cotton therewith, in order to see whether the undissolved particles of alumine, so united to the colouring matter of the bark, would become the basis of a lasting colour. I found, however, by repeated trials, that cotton in this way could only be made to imbibe a pale yellow, which probably adhered to the surface only of its fibres, because it was nearly destroyed by a single week's exposure to the sun and air. Wool, however, in this way received a brownish yellow of sufficient body and considerable durability.

Ammoniac,

Ammoniac, or volatile alkali, whether mild or cauſtic, appears to diſſolve alumine ſo very ſparingly, that hitherto I have found no conſiderable benefit from any ſolution of this kind as a mordant. Nor have I ſucceeded much better with either the carbonated (mild) potaſh, or that of ſoda, their action not being conſiderable upon the earth of alum. But if this earth, obtained by precipitation and waſhing as before mentioned, be digeſted whilſt moiſt with a ſtrong lixivium either of potaſh or of ſoda, in its pure or cauſtic ſtate, in a mattreſs placed on a ſand heat, nearly approaching that of boiling water, it diſſolves very copiouſly, and may afterwards, by evaporation, be made to cryſtalize. The celebrated Macquer appears to have believed that very beneficial effects might be obtained in dying by theſe combinations, and more eſpecially when uſed as mordants for the madder red on cotton. It ſeems evident, however, that he was greatly miſtaken reſpecting the true nature of thoſe operations upon which this belief was founded; and that in the proceſs for Turkey reds, where he ſuppoſed the durability of colour to reſult principally from a combination of this kind, no ſolution of aluminous earth by any alkaline menſtruum could have taken place; and though Mr. Hauſſman appears alſo to have formed conſiderable expectations of advantage from the application of theſe ſolutions of alumine by potaſh or ſoda, I have been led by the reſults of many trials, to concur in opinion with Mr. Berthollet, that but little good is to be expected from them, unleſs it be under the circumſtances which I ſhall preſently explain, becauſe the alkaline menſtruum evidently has too much affinity to the particles of alumine to allow of their being depofited and fixed in the fubftance, to be dyed fo copioufly as is neceffary; and I have repeatedly found, that after having foaked cotton a fufficient time in the diluted folution of alumine by either potafh or foda, the bafis was almoft wholly carried off or removed by only rincing the cotton in water to fit it for being dyed, and that only very feeble colours could be raifed upon what remained of the alumine as a bafis. This was more efpecially the cafe where the folution of alumine had been made by potafh, which by attracting moifture from the atmofphere, rendered it difficult to dry the cotton fufficiently when impregnated therewith, at leaft without artificial heat. Thefe defects were, however, removed, and a *very excellent durable yellow* produced by putting the cotton which had been *firft* foaked in a diluted folution of alumine by potafh, into water which had diffolved as much common alum as it could retain, whilft blood warm, macerating and turning it therein for the fpace of half an hour, (during which the potafh and fulphuric acid combining, each precipitates the alumine of the other,) then drying the cotton, and afterwards immerfing it in lime-water; then drying again, rincing and dying it with the bark as before directed. The yellow given in this way faded but very little by two months expofure to fun and air in the midft of the Summer; nor was it fenfibly weakened by the action of ftrong French vinegar, or of the oxygenated muriatic acid. The folution of alumine by foda produced equally good effects in this way.

Nitrate of alumine (made by faturating the nitric acid with moift alumine as before mentioned,) being diffolved in eight times its weight of water, and ufed inftead of the folution of common alum laft mentioned, produced a yellow rather better and more durable even than the laft. Cotton which had received no impregnation, being macerated in a like folution of the nitrate of alumine, then dried, immerfed in lime water, rinced and dyed with the bark, received a yellow confiderably better than I could obtain with a folution of common alum in the fame way.

Muriate of alumine generally produced with the bark, effects as good, but not materially better than thofe refulting from common alum ufed in the fame ways.

In dying any of the yellows before mentioned with bark, the colour may be raifed to an orange by employing a fuitable proportion of madder along with the bark.

It can hardly be neceffary for me to mention, that linen or cotton, either fpun or wove, when previoufly dyed blue of a fuitable fhade in the ufual ways, will be rendered green by fuperadding the Quercitron yellow in the ways, and by the means already directed for dying this yellow upon linens and cottons not previoufly made blue, taking care to proportion the quantum or body of each of the component blue and yellow colours to the particular fhade of green which they are intended to compofe or produce.

Linen and cotton foaked four hours in a mordant made by diffolving lime in muriatic acid, and

and mixing the ſolution with ſix times its weight of water, afterwards dryed, rinced, and dyed with Quercitron bark, took a full drab colour which reſiſted the action of ſun and air for a conſiderable time: but neither the ſulphate nor the nitrate of lime employed in this way with the bark, gave any thing more than buff or ſlight nankeen colours of little durability.

Magneſia diſſolved by the ſulphuric, the nitric, muriatic, and acetous acids, and uſed in this way as a mordant, produced, with bark upon linen and cotton, weak drab, cinnamon, and nankeen colours, which, however, proved too fugitive to be of any uſe.

Cotton ſoaked in a diluted ſolution of flints, made as mentioned in a former part of this volume, and afterwards rinced and dyed with the bark, became of a nankeen colour ſomewhat laſting.

Among the metallic baſes, that of tin might naturally be expected to produce the moſt beneficial effects by *general dying* upon linen and cotton with the Quercitron bark; but hitherto my experiments therewith, though they have been very numerous and greatly diverſified, afford no ſucceſsful reſults: for though different ſolutions of tin, (particularly the nitro-muriatic and the murio-ſulphuric,) when diluted and applied as mordants to linen and cotton, enable theſe ſubſtances afterwards to imbibe yellows exceeding all others in brightneſs, luſtre, and beauty; and though theſe yellows are capable of reſiſting the action of boiling ſoap ſuds, as well as of ſtrong acids,

acids, not excepting the oxygenated muriatic acid, yet they decay very ſpeedily when expoſed to the ſun and air, ſo as even to ſuffer more in a ſingle week than the Quercitron yellows dyed upon an aluminous baſis commonly ſuffer in a month. The tin baſis is, moreover, accompanied with this *ſingular* circumſtance, that when applied ſeparately to the linen or cotton intended to be dyed, and when theſe ſubſtances, after the uſual drying and rincing, are dyed with the bark, the colour, (contrary to what happens with the aluminous baſis,) proves much more fugitive than it does when the ſolution of tin and decoction of bark are firſt mixed together, and afterwards applied to the linen or cotton proſubſtantively; nor have I ever been able to apply any of the ſolutions of tin even in ſmall quantities mixed with an aluminous mordant upon linen or cotton, without perceiving that the colour afterwards obtained thereby from bark was much leſs durable in reſpect to ſun and air, than it would have been with an aluminous baſis only. I ſhall, however, abſtain from giving any opinion reſpecting the cauſe of theſe defects, until the reſults of ſome nice and difficult experiments, which ſucceſſive interruptions have hindered me from bringing to a ſatisfactory concluſion, ſhall enable me to do ſo on better grounds than I poſſeſs at preſent.

Zinc diſſolved by different acids, and employed as a baſis for dying with Quercitron bark on linen and cotton produces browniſh yellows, inclining more or leſs to the olive and drab colours; they ſeem, however, leſs durable than the like colours, which may be more conveniently

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and cheaply given by substituting solutions of alum and of iron, mixed in different proportions, as mordants.

Bismuth being dissolved in nitro muriatic acid, and the solution afterwards sufficiently diluted by water, and cotton being soaked therein for two hours, then immersed in lime water, dried, rinced, and dyed with Quercitron bark, it took a very high and full, but at the same time a very brownish yellow, of considerable durability.

Copper dissolved in the sulphuric, the nitric, muriatic, and acetous acids, and afterwards sufficiently diluted with water, being applied to linen and cotton as a mordant, enables them to obtain from Quercitron bark by dying, different shades of full but brownish yellow, which, however, does not long bear washing with soap, or exposure to rain, sunshine, and air; the oxyd of copper, on which the colouring matter is applied, being readily acted upon by all these agents. Soaking the linen or cotton in lime water when impregnated with the oxyd or solution of copper, previous to the dying with bark, renders the colour more durable.

Cotton having been soaked two hours in a diluted ammoniate of copper, and then hung out to dry, appeared at first of a fine blue colour, but afterwards became of a very beautiful bluish green. A bit of this cotton being dyed for a few minutes in a decoction of Quercitron bark, became of a fine yellowish green: another bit dyed in the same decoction for a longer time became of a dark brownish yellow colour; this was, however,

ever, changed to a lively yellowiſh green, by waſhing with ſoap, and ſuffered but little during three weeks expoſure to ſunſhine, air, and rain.

Linen or cotton ſoaked in a diluted nitrate of lead, then in lime water, and afterwards rinced and dyed with Quercitron bark, took a kind of nankeen brown colour ſomewhat, though not very, durable.

The other ſolutions of lead appear to be ſtill leſs uſeful as mordants upon cotton for dying with the bark.

Mangane∫e being diſſolved by a very weak or diluted ſulphuric acid, and the ſolution afterwards mixed with an additional portion of water, cotton was ſoaked therein for two hours, and afterwards immerſed in lime water, then rinced and dyed with the bark, from which it obtained a nutmeg brown colour inclining ſlightly to the olive, which proved ſomewhat laſting.

The oxyd of arſenic is capable of ſerving as a mordant for the Quercitron colouring matter, but as the ſhades produced by it may be obtained by cheaper and much leſs dangerous means, I cannot recommend its uſe for this purpoſe.

Cotton ſoaked in a diluted nitro muriate of gold, afterwards rinced and dyed with Quercitron bark, received a delicate olive tinged yellow of conſiderable durability; but this mordant

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is much too expensive to be used in this or in almost any other way.

Cotton first dipped in a weak solution of soda, became of a yellowish brown by being soaked in a diluted solution of platina by the nitro-muriatic acid, and being afterwards dyed with the bark, it became of an olive colour.

Cotton dipped in a weak solution of soda, and then in a diluted solution of the grey ore of Cobalt, (*Cobaltum Galena,*) in the muriatic acid, became first green and then yellow; and this being afterwards dyed with Quercitron bark, the colour changed to a lasting black. The pure Cobalt, dissolved either by the muriatic or the nitric acids, and applyed in this way to cotton, produced a cinnamon brown colour, with the Quercitron bark.

Cotton wetted with a solution of soda, and then with a diluted nitrate of nickle, became green, and being afterwards dyed with the bark, it became of a full cinnamon brown.

*Iron*, though I mention it last, seems to be the most useful of the metallic bases for dying on cotton and linen with the Quercitron bark, and more especially for producing the drab, mud, dove, and olive colours, with the great variety of shades which result from a mixture of these upon cotton velvets, velverets, fustians, &c. These colours have hitherto been commonly dyed from what is called the old fustic, (*morus tinctoria,*) though they may be given more cheaply and conveniently with the Quercitron bark in the same

ſame ways, and when ſo given, are more laſting than thoſe given by fuſtic, as I have repeatedly found by expoſing ſamples of each to rain, ſun, and air, for the ſpace of ſix months together.

The cheapeſt form in which iron can be employed in this way, is that wherein it is diſſolved by ſulphuric acid, as in the common ſulphate of iron or green copperas; and after many trials I have not found any other combinations of this metal capable of producing effects ſo much better in dying as to compenſate for the increaſed expence attending their uſe. Copperas and Quercitron bark, in different proportions, produce all the different ſhades of the *drab* colour, from the deepeſt to the lighteſt; and for this purpoſe, the copperas may be either diſſolved in a decoction of the bark, and the pieces of cotton velvet, velveret, or fuſtian turned through the liquor (of a ſuitable heat) by the winch, or the bark may be boiled with water in one veſſel and the copperas diſſolved by warm water in another, and the pieces paſſed as uſual, firſt through the latter and then through the former, and ſo alternately from one to the other, until the proper ſhade is acquired; and by adding after the rate of one pound of chalk to eight pounds of copperas in the veſſel wherein this laſt is diſſolved, the colour will be rendered more durable, and at the ſame time changed a little to the chocolate brown.

To produce the olive ſhades, ſulphate of copper (blue vitriol) with about one-eighth part of its weight of chalk, or alum with a like proportion of chalk, may be employed along with the copperas,

peras, ſo as to give the drab colour a ſufficient inclination towards the yellow hue; and for this purpoſe the blue vitriol is, I think, preferable to alum.

For the drab colours, one or two pounds of copperas, according to the fullneſs of colour wanted, with about three times as much bark as of copperas, and a little chalk, will ſuffice to dye 100lb. weight of velvet, velveret, or fuſtian: and for the olives, it will only be neceſſary to diminiſh the quantity of copperas according as the ſhade is wanted to incline more or leſs to the yellow, and add as much or a little more blue vitriol in its ſtead: and for this purpoſe the blue vitriol may be either diſſolved in the ſame veſſel with the copperas (and chalk,) or it may be diſſolved with chalk in a ſeparate (third) veſſel, and the velvets or fuſtians, after they have been turned or worked ſufficiently, in the two firſt veſſels, containing, one the copperas liquor, and the other the bark liquor, may be turned or worked in the ſolution of blue vitriol in the third veſſel, until it inclines ſufficiently to the yellow hue; and perhaps this method will generally be found moſt convenient to fuſtian dyers, who are frequently required at the ſame time to dye a great variety of different ſhades. But otherwiſe it probably would be moſt advantageous to turn and ſoak the pieces for a little time in the ſolution of copperas and chalk, or of copperas, chalk, and blue vitriol, (or alum inſtead of blue vitriol,) then immerſe them for a few minutes in lime water, and afterwards rince and dye them in a decoction of bark, by which, colours much more laſting and much leſs liable to ſpot than thoſe commonly obtained, might be dyed; it would, however, be more difficult in this way to produce that great variety of ſhades, which in the other are eaſily attained by any dyer accuſtomed to the uſe of old fuſtic for the like purpoſes, as I well know by my own experiments and by thoſe of others. One pound of bark will commonly produce as much effect as four pounds of old fuſtic.

When darker colours are wanted, than can be conveniently given with the Quercitron bark and copperas, a portion of Spaniſh ſumach may be added to obtain them, as is done for ſaddening the colours given with old fuſtic and copperas; though it is poſſible to produce a durable colour, approaching very nearly to a *perfect black*, by the Quercitron bark and the iron baſis, by firſt ſoaking the cotton in a weak ſolution of barilla and liver of ſulphur, then drying and immerſing it in a diluted ſolution of iron, by the nitro muriatic acid, and afterwards dying it with the bark.

## *Of the Application of Quercitron Bark in Topical Dying or Callico Printing.*

Between the 170th and 179th pages of this volume, I have given a general though ſummary account of the art of callico printing, as practiſed during many ages by the inhabitants of India; and alſo of the improvements which have followed the introduction of this art into Europe. I have alſo particularly deſcribed the two principal mordants or baſes employed to fix and raiſe the different adjective colours, by topical or partial dying; I mean the printers' aluminous mordant or acetite of alumine, and what is called iron liquor (acetite of iron), made by diſſolving that metal in vinegar, ſour beer, &c. Theſe mordants the callico printers have very improperly named colour or colours, though they only afford the baſis or baſes of colour, to be afterwards obtained from madder, weld, Quercitron bark, &c. For an account of the preparation of acetite or ſugar of lead, and of the ſubſtitutes for it, in making the aluminous mordant, I cannot do better than refer my readers to Mr. Berthollet's chapter on that ſubject, and to the writers therein mentioned; and, for an account of the true nature and advantage of this aluminous mordant, my readers will be pleaſed to recur to pages 176, 177, 178, 179 and 180 of this volume. Of the iron liquor, it may be proper to obſerve, that, when made with vinegar, that which has been longeſt kept is moſt eſteemed. But of late much is conſumed, which has been prepared by diſſolving iron more expeditiouſly in the pyro ligneous acid obtained by diſtillation from wood and from tar; and it is probable that, in ſome caſes, the action of this acid has been ſtrengthened by an addition of the muriatic, though this laſt muſt have a tendency to render the ſolution corroſive.

Linens or cottons, before they are printed, require to be bleached; and the more perfectly this operation is performed either by the old or new method, the leſs will the parts intended to remain white be afterwards ſtained by the madder, weld, or bark liquors in dying; and the more eaſily will any diſcolouration from theſe liquors be afterwards diſcharged. After bleaching, the pieces will need to be calendered, in order to produce a ſmooth ſurface, and render the woof and ſhoot as even and ſquare as poſſible, and thereby favour a due application of the mordants; which, being firſt properly thickened by ſtarch, flour, or gum, as formerly mentioned, are to be applied by blocks, plates, cylinders, &c. as thoſe employed in this part of the buſineſs ſufficiently underſtand. This being done, the pieces are to be well dried in a ſtove heat, ſo as to evaporate the acetous acid, holding the baſis in a ſtate of ſolution, and cauſe the latter to be more copiouſly depoſited and fixed in the pores of the cloth.

After drying, the cleanſing operation follows; and this is performed in a ciſtern with water, nearly as warm as the hand can well bear, and a quantity of freſh cow-dung; in which the pieces are to be briſkly worked, ſo as to diſſolve the thickening of the mordant or mordants, and ſeparate all the unfixed ſuperfluous particles of alumine or of iron, which the cow-dung ſerves to entangle, ſo as to hinder them from ſpreading and attaching themſelves to the parts intended to be kept white, and there becoming the baſis of a future ſtain or diſcolouration, which it might be difficult to remove; after this the pieces, being thoroughly ſoaked and well rinced in clean water, will be fitted for dying with the bark.

In many caſes, madder colours are to be mixed in the ſame piece with thoſe of the bark; but in theſe the madder ought to be firſt dyed on a ſeparate courſe of work, in which the mordant or mordants are printed only ſo far as the madder colours are intended to extend; and the pieces being then dried, cleanſed, and dyed with the madder, and afterwards whitened by braning and bleaching, are to be calendered, and made ready to receive a ſecond courſe of mordants for the bark, in which the pieces are to be printed, dried, cleanſed, &c. as juſt mentioned.

My readers have been already informed, that the bark produces a good bright yellow with the aluminous mordant, and a drab colour with the iron liquor; and that both together mixed in different proportions, produce different ſhades of olive and olive-brown colours. And that if a ſtrong decoction of galls be added to the iron liquor, and the mixture applied in the ſame way to linen or cotton, it will, by dying with the bark, produce a black ſufficiently fixed, though inclining a little to a browniſh hue. By means, therefore, of the aluminous mordant and the iron liquor, three very diſtinct colours beſides the black are obtained from Quercitron bark: and moreover, by applying the aluminous mordant upon a madder red and an Indigo blue, an orange in the firſt caſe, and a green in the ſecond, will be produced when the piece comes to be dyed with the bark.

I have already noticed (at page 186) the practice of colouring the ſolution of alum, in the Eaſt Indies, with ſampſan or ſappan (red) wood; a practice which the callico printers of Europe have imitated, by colouring the aluminous mordant with Braſil wood, (and thence calling it *red* colour,) not only when it is intended to ſerve as a baſis for the madder red, but alſo for the Quercitron or weld yellows; though in the latter caſe at leaſt, the practice ought to be laid aſide.

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It is indeed neceſſary that ſome tinge ſhould be given to mordants in callico printing, in order that the printer may readily diſcern the exact progreſs and extent of his work: but it is much better to give this tinge, from Quercitron bark, to figures or parts intended afterwards to receive the bark or the weld colours by dying, than to give it from Braſil wood; the colour of which, were it to remain, would hurt the true yellow intended to be afterwards fixed upon the aluminous baſis: but the falſe Braſil colour, not having ſo much affinity with the baſis as to be able to maintain its ſituation, is always diſlodged by the ſuperior affinity of the bark or weld. This diſlodgment, however, of one colouring matter by the application of another, takes up ſome time, and unneceſſarily prolongs the dying proceſs (the yellow in this caſe riſing more ſlowly); and the parts intended to be kept white are alſo rendered liable to a greater degree of ſtain or diſcolouration. But, where the mordant has been tinged with the Quercitron bark, a portion of the colour intended to be given is already applied to the baſis; and, though at firſt not perfectly fixed upon the linen or cotton, it ſoon becomes ſo in the dying veſſel; whilſt the additional colouring matter of the bark, having no falſe Braſil wood colour to diſlodge, applies itſelf without impediment to the aluminous baſis, and produces the requiſite degree of colour much more quickly, as may be eaſily ſeen upon a proper trial.

I do not indeed think that any degree of tinge ought to be thus given, even from the bark, *beyond* what is neceſſary to enable the workman to ſee his work with ſufficient clearneſs; becauſe the particles of alumine or of iron, when previoufly united to any fpecies of colouring matter, do not feem by cold application to fix themfelves either fo intimately or fo *copioufly* in the fibres of linen or cotton, as they do when applied without any fuch union or incumbrance; and I have repeatedly found that yellow colouring matter, dyed upon an aluminous bafis *untinged*, produced a more lafting colour than it does upon a bafis previoufly tinged even by Quercitron bark, and much more lafting than where the tinge had been given with Brafil wood. And this fact will enable us to conceive one at leaft of the reafons why it is moft advantageous, in dying upon linen or cotton, to apply the aluminous bafis firft by itfelf alone. But, in topical dying with the Quercitron bark or with weld, wherever it is neceffary to give a moderate degree of tinge to the mordant, whether aluminous or ferruginous, (i. e. iron liquor,) or a mixture of thefe, I muft ftrongly advife it to be given by a decoction of the bark made very ftrong, that it may not too much weaken the mordant, and at the fame time employed as fparingly as the nature of the cafe will permit. The effect of mordants topically applied, often depends greatly upon their being either too much or too little thickened with gum, ftarch, or flour, which are ufually employed for this purpofe. When the liquor has been too much thickened, it does not fufficiently penetrate the fibres or fubftance of the linen or cotton, and therefore the colour raifed upon it proves weaker and lefs durable than it otherwife would do: but on the contrary, if the liquor be not fufficiently thickened, it runs or fpreads too far upon the furface of the piece, and produces figures or impressions which prove confused and undefined. In general the liquor for this kind of application should be made so thick, and only so thick, as barely to prevent its spreading beyond the proper limits; and it seems more necessary to catch exactly this point of thickness or fluidity with the iron liquor than with the aluminous mordant, because the oxyd of iron does not combine so intimately as the alumine does with the acetous acid; but, on the contrary, it remains suspended in a less divided state, and neither penetrates so freely nor unites so intimately as the particles of alumine with the linen or cotton to which it is applied; and therefore the iron liquor in particular ought never to be thickened any more than is necessary to hinder it from spreading too far.

When the mordant has been applied, and has had sufficient time to penetrate the substance of the cloth, it should be thoroughly dried in air artificially heated as before mentioned, so as to evaporate not only the water, but as much as possible of the acetous acid united to the alumine, or to the oxyd of iron, in order that nothing may remain to oppose their intimate union with the fibres of the linen or cotton, which the water, and more especially the acid, necessarily would do, by exerting their own particular affinities upon the substances intended to be thus intimately united. It will however be impossible in *this* way to evaporate the *sulphuric* acid, of which the aluminous mordant, made with the usual proportions of alum and sugar of lead, alway contains a little; and which, when the pieces are brought under the cleanſing operation, enables the warm water to re-diſſolve and ſeparate a part of the alumine, wanted for raiſing and fixing the colours intended to be afterwards given by dying; which alumine, being ſo re-diſſolved and ſeparated, is apt, even in ſpite of the viſcidity and entanglement of the cow-dung, to fix itſelf again upon thoſe parts of the linen or cotton intended to remain white, and occaſion a much greater and more laſting degree of ſtain or diſcolouration than would otherwiſe take place in the dying veſſel. Theſe effects might indeed be obviated, by mixing a little lime or chalk with the cow-dung and water employed for the cleanſing, ſo as to neutralize the ſulphuric acid; but, by ſo doing, a ſulphate of lime would be produced; and this, by fixing itſelf on the parts intended to be kept white, would give them a calcareous baſis, and occaſion another kind of ſtain or diſcolouration as bad as that intended to be thus prevented. But carbonate of pot-aſh or mild vegetable alkali, uſed in this way inſtead of lime, will anſwer the purpoſe of neutralizing the ſulphuric acid, without communicating any improper baſis of colour, ſo as to occaſion that kind of ſtain or diſcolouration which it is ſo deſirable to avoid; though if any more of it be uſed than what is ſufficient barely to neutralize the acid in queſtion, it will exert a miſchievous action, by diſſolving a portion of the aluminous baſis fixed upon the linen or cotton, and render the yellow afterwards communicated by dying more feeble than it otherwiſe would have been. A *very little* of the mild vegetable alkali may however be uſed in this way with advantage, ſo as to leave the pieces capable of receiving

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full ſtrong colours, whilſt the parts intended to remain white will be but very ſlightly diſcoloured by the dying proceſs, and afterwards eaſily whitened. The mild vegetable alkali does not diſſolve the oxyd of iron, and therefore may be uſed in this way with leſs caution to pieces printed only with the iron liquor.

It is in all caſes of great importance, that the cleanſing operation ſhould be well conducted, and thoroughly performed; but more eſpecially where a large proportion of drab, dove, and olive colours are to be intermixed with yellows; becauſe the oxyd of iron, which ſerves as a baſis to the former, is very apt to attach itſelf too copiouſly to the linens or cottons on which the iron liquor is printed; and unleſs the redundant part be carefully removed in the cleanſing operation, (which is a work of ſome difficulty,) it will remain, and be afterwards attracted and ſeparated by the colouring matter of the bark in the dying veſſel; and, uniting therewith, it will give the dying liquor an olive or drab colour tinge, and greatly tarniſh the yellow figures or deſigns, as well as ſtain the parts intended to be kept white; and, therefore, whenever the iron liquor is to be printed upon the ſame piece with the aluminous mordant, the former ſhould be diluted as much as it will bear, without making the liquor too weak to afford a ſufficient baſis for the colour intended to be afterwards dyed upon it. By ſuch dilution, joined to proper care in cleanſing, the yellows may be made to come out of the dying liquor perfectly untarniſhed; which otherwiſe they will not do, at leaſt when accompanied with any conſiderable proportion of figures or

deſigns

designs which have been printed with iron liquor.

Having premised thus much concerning the operations of printing and cleansing, I now proceed to that of dying with the Quercitron bark. For this, a suitable portion of the bark, previously ground, is first to be put into a dying pan or vessel with cold water, and the pieces to be dyed immediately after; a small fire is then to be lighted under the pan, so as gradually to warm the water; and, while this is doing, the pieces are to be slowly turned by the winch, in order that the colouring matter may apply itself equally: when the liquor becomes a little more than blood warm, the colours will take sufficiently quick, and prove more lasting than they do when raised more hastily; because in a moderate warmth the colouring particles (as was before observed) have time, and are enabled to adjust themselves more accurately, and unite themselves more closely to the particles of alumine, than they can do when hastily thrown and accumulated by a greater heat upon the printed figures or designs. And I have repeatedly found, that samples slowly dyed with the bark in this way, being exposed to the sun and air along with others dyed more expeditiously in a boiling heat, proved much the most lasting. And if the Quercitron yellow has at any time been found less durable than that of the weld, it can only have been so through some defect in the mode of dying, at least if there was none in the mordant. Hitherto the bark has generally been used with too much heat *at first*. I say at *first*, because after the

colour

colour has been ſlowly raiſed, by liquor moderately warm, to nearly the proper height, a boiling heat will do no harm, excepting that of occaſioning a little more ſtain or diſcolouration upon the parts intended to remain white; and though the avoiding of this is an additional motive for applying the bark in water of a moderate warmth only; yet this of itſelf might not be a very powerful motive, becauſe ſuch ſtains from the bark are much more eaſily removed than thoſe reſulting from weld. But the moſt eſſential difference between theſe vegetables, reſpects the degree of heat by which their ſeveral colours are moſt permanently fixed upon linen or cotton; that of weld requiring at leaſt a ſcalding if not a boiling heat to render it laſting, whilſt the bark colour, as has been already obſerved, proves moſt durable when applied in water but little more than blood warm. And indeed I have found, during the Summer months, that cottons printed with the aluminous mordant were able to imbibe a good, though not a very high yellow, by only remaining a few hours with bark in water of the heat of the open air, (in which it was placed,) and without any perceptible ſtain or diſcolouration upon the parts not printed. A piece of the callico ſo dyed in the heat of the atmoſphere only, being cut off and farther dyed with the bark in boiling water, it imbibed a greater body of colour; but a ſample of this and of the former or paler yellow being equally expoſed to the ſun and air, I found at the end of three weeks, that the latter, which had been the deepeſt, retained no more body than the other; the additional colouring matter, which in a boiling heat had been enabled to apply itſelf upon the aluminous baſis,

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having been all difcharged during this expofure to the weather. A fact which feems to indicate, that when the alumine has attracted to itfelf a certain portion of colouring matter, any addition made to it afterwards by the aid of heat, will be lefs permanently fixed, and therefore liable to be more fpeedily removed by any of the caufes which ufually contribute to the decay of colours.

All the different fhades of yellow may be obtained from the Quercitron bark by varying the quantity, and applying it with greater or leffer degrees of heat during a longer or fhorter time. By ufing the bark fparingly in water only blood warm, pale delicate yellows may be raifed in about fifteen or twenty minutes, and the parts intended to be kept white will receive fcarcely any difcolouration; by a larger proportion of bark, and by keeping the pieces for a longer time in the dying liquor, though without increafing its heat, a full and clear lively yellow may be produced; and by a ftill greater proportion of the bark, and a prolongation of the dying operation in a fcalding heat during the latter part of it, the colour may be raifed firft to a high golden, and afterwards to a very full brownifh yellow. The quantity, therefore, of bark to be employed muft always depend upon the nature and clofenefs of the figures or impreffions which are to be dyed, and the height or fullnefs of colours intended to be produced. Commonly, however, one or two pounds of bark will fuffice for each piece; but, where too little has been employed at firft, a farther quantity may be afterwards added without inconvenience; and, when the dying

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is to be performed in a very moderate heat, it will always be moſt advantageous to employ a little more bark than is neceſſary; which may be done without any loſs of colouring matter, becauſe other pieces may be afterwards dyed, with a farther ſupply of bark, in the ſame liquor; and I have found that yellows, whether dyed from bark or weld, commonly prove moſt durable when the dying liquor has been ſomewhat plentifully ſtored with colouring matter; and in general I think it beſt to employ the bark ſo freely, as that the liquor may be ſtrong enough without being made more than blood warm, to produce full bright yellows in the ſpace of half or three quarters of an hour; the tinge or diſcolouration which the parts not printed imbibe from the bark in this way not being half ſo great as that produced by weld, and it being afterwards diſcharged with leſs than half the time and trouble which even an equal degree of ſtain from the latter would require. Indeed, where the pieces have been at firſt well cleanſed from all looſely adhering and ſuperfluous particles of the aluminous or ferruginous baſes, the diſcolouration from bark generally proves ſo inconſiderable, that by rincing or waſhing them in cold, and more eſpecially in warm water, it may be ſufficiently removed without either braning or bleaching, excepting where the unprinted parts are required to be uncommonly clear and white: and when this is the caſe, I think it beſt to add after the rate of one pound of cream of tartar, in powder, for every twelve or fourteen pounds of bark, putting the tartar into the water immediately after the bark, and then dying the pieces, as I have already explained. The tartar uſed in this way

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will contribute much towards keeping the white or unprinted parts free from ſtain or diſcolouration; and it will, moreover, give the Quercitron yellow that bright, clean, and delicately greeniſh hue which is ſought for in the weld, ſo as to make the former reſemble the latter. But, as the tartar tends to keep the Quercitron yellow from taking ſo faſt or riſing ſo high as it would otherwiſe do, the liquor may, in this caſe, be made hotter in the latter part of the operation. On the contrary, if, inſtead of tartar, one pound of clean white pot-aſh be added for every thirty pounds of bark, a very high, and at the ſame time a very bright yellow will take ſo quickly, that the liquor ſhould never be more than blood warm: and, though the unprinted parts may ſeem a little more ſtained than they are when no pot-aſh is uſed, the ſtain will be diſcharged by thoroughly rincing and waſhing the pieces as uſual.

Some callico printers, not acquainted with the beſt methods of employing the bark, have thought proper to join with it a little of the decoction of weld: I cannot, however, recommend this practice, becauſe in truth the bark, when properly uſed, wants no ſuch aſſiſtance, and becauſe the colouring matter of the weld does not take permanently without a greater degree of heat than ought to be employed with the bark. It moreover occaſions a much greater ſtain upon the unprinted parts, and at the ſame time degrades the madder reds and purples, (where theſe colours have been previouſly dyed,) much more than the bark.

It is to be obſerved, that the very moderate warmth, which beſt ſuits this kind of dying with the bark, does not, in general, completely extract its colouring matter, at leaſt from ſuch parts thereof as are not finely ground; but, being tied up in a bag, it may be afterwards boiled ſeparately in water, and the decoction ſo made may be employed for dying olive and drab colours, where they are not intermixed with yellows, or reds. Some callico printers have, indeed, thought it beſt, in all caſes, to begin by boiling the bark in a ſmall quantity of water, ſo as fully to extract the colouring matter, and then, for yellow as well as drab and other bark colours, to put a ſuitable proportion of the decoction into the dying veſſel, with clean warm water, and dye the pieces therein, adding more of the decoction as wanted from time to time. I do not, however, think this practice ſo convenient as what I have recommended.

A very ingenious printer in a diſtant country and warm climate, ſome time ſince favoured me with an account of his method of uſing the bark, which he conſiders as one of the beſt: "I pound (ſays he) the bark, and boil it in a good quantity of water, ſay twenty-five gallons to ſeven pounds of bark; after which I let it ſettle, and pour off the clean decoction; of which I add a portion to a tub full of clean cold water, and immediately, with the hand, paſs a quantity of clean rinced (printed) cloths through the water; they take on colour very quickly, and it appears freſh and beautiful: I then add another portion of the decoction, and bring out a pretty full yellow; meanwhile I have my large copper ready with

with clean water as warm as the hand can well bear, and to this I add alſo a portion of the decoction; and then remove the cloths from the tub into the copper, and turn them quickly round; by which method I obtain the beſt and moſt durable yellows: ten or fifteen minutes will be long enough to keep the cloths in warm water, where a delicate yellow is required." "I found it eaſy," continues the writer, "to manage the olive and drab colours in the copper; for *theſe*, I uſe the bark which has been once boiled for the yellow; ſeven or eight pounds of it are to be boiled in twenty-five gallons of water, and then the whole is to be thrown into a copper containing about 250 gallons; through which I paſs about 225 yards of cloth perfectly well rinced, or, if it be heavy work, only about 180 yards, which are to be turned quickly round: I begin with a moderate fire, which in half an hour is to be raiſed ſo as to make the water almoſt boil. Here, and eſpecially for *dove* colours, I uſe a little ſumach, which requires conſiderable heat before it produces any good effect; and therefore I think it uſeleſs for yellow, which the bark produces with ſo little heat. I have ſeldom allowed more than an hour for ſuch olives, drabs, and doves; and I never join yellows with them, becauſe the grounds will in this way be ſo much ſtained as to require more bleaching than the yellows can bear without injury; but doves, olives, and drabs ſtand the bleaching, and remain unimpaired after the grounds are become perfectly white." This account the writer concludes by ſaying, "I have been able to do more variety of work with the bark than with any other colouring matter yet known; it is pleaſing to work with, as it

takes

takes effect quickly, and is very eaſily managed by any perſon who knows the buſineſs of neutralizing ſalts, and preparing cloth to receive colour."

The rule which this gentleman ſeems to have preſcribed to himſelf, of never joining the drab and dove colours to the yellow, is, I believe, much too rigid; for though, in truth, it is impoſſible to dye perfectly bright yellows where they are intermixed with any conſiderable proportion of what is called the *black colour*, and difficult to do it where the drab and dove colours abound very much; yet, in the latter caſe, this difficulty may be very much diminiſhed by uſing the iron liquor of no greater ſtrength than is neceſſary, and taking care to have the pieces thoroughly cleanſed (as lately mentioned) before they are put into the dying veſſel: if this be done, a conſiderable portion of olive, drab, and dove colours may be intermixed, and even a little of the black, without any material degradation of the yellow. To improve the black, and darken the drab or dove colours, (which the printer is often deſirous of doing,) a little Malaga ſumach, (*rhus coriara*,) in powder, may be advantageouſly employed with the bark, after the rate of one pound of the former to three or four of the latter. It is, I believe, generally thought beſt to raiſe the colours firſt with the bark, and afterwards change or darken the doves and blacks by adding the ſumach, and continuing the proceſs until the deſired effects have been produced. My own experiments, however, lead me to conclude, that time may be ſaved, and every good purpoſe attained with equal certainty, by putting the ſumach into the dying veſſel along with the bark, and thus applying the colouring matters of both at the ſame time; taking care, however, not to heat the dying liquor beyond what the hand can bear. In this way the parts unprinted may be kept perfectly white, ſo as never to need either bleaching or braning. The ſumach, indeed, when put into the water at the ſame time with the bark, and uſed in this way, produces, in an extraordinary degree, the effect of keeping the white or unprinted parts perfectly clear and free from all diſcolouration; which it probably does by means of a *particular acid* contained in this and many other aſtringent vegetables: One pound of ſumach to three of the bark will be amply ſufficient for this laſt purpoſe; and in that proportion the ſumach will make the parts printed with iron liquor incline towards a purple colour inſtead of the drab, which Quercitron bark uſed *alone* would produce.

This change of colour produced by ſumach will ſometimes render the uſe of it inconvenient; but when this is not the caſe, a ſmall proportion thereof joined to the bark, as before mentioned, will prove more effectual than cream of tartar in preventing even the ſlighteſt ſtain or diſcolouration upon the unprinted parts of cottons topically dyed.

A gentleman, of whoſe information I have more than once availed myſelf, ſome time ſince brought from Bengal, and gave me a parcel of the dried leaves and tops of a plant there called D'howah, and employed, as he informed me, in the dying of topical or field colours by putting

ting a ſmall quantity of it into the copper when the colours begin to riſe, in order to keep the grounds or unprinted parts clear; an effect which, upon trial, I found it produce nearly as well as ſumach; and upon dying a bit of cotton which had been printed with iron liquor and the aluminous mordant ſeparately, in a decoction of this plant only, it imbibed colours very nearly reſembling thoſe of ſumach, though the decoction itſelf, even when made very ſtrong, did not diſcover any aſtringency to the taſte.

The berries of the common Pennſylvanian ſumach *(rhus glabra)* are covered with a red farinaceous matter, containing a large proportion of an acid which I believe to be the oxalic. Theſe berries employed with the Quercitron bark, after the rate of one pound of the former to twelve of the latter, produced effects nearly ſimilar to thoſe of cream of tartar, as already mentioned, in preſerving the unprinted parts of cottons from being ſtained, and in giving the Quercitron yellow the pale greeniſh complexion which diſtinguiſhes that of weld. Such means cannot, however, be employed where very full high yellows are wanted; and when this is the caſe, if the grounds or unprinted parts are required to be perfectly clear and white, it may be beſt to employ a little clean pot-aſh in the dying, as lately mentioned, and afterwards to ſpread the pieces for a day or two upon the graſs, laying what is called the wrong ſide upwards, as is practiſed with other field colours. Thoſe of madder and weld indeed always require this operation, though it cannot be wanted for thoſe of the bark, except in the ſingle caſe juſt mentioned; and then only for a very ſhort time, unleſs it be in rainy cloudy weather, when this kind of bleaching proceeds very ſlowly with all colours, becauſe the action of the air is then not only unaſſiſted by the rays of the ſun, but obſtructed by the water which it holds in a ſtate of ſolution.

Meſſrs. T. H. and ſon, very ingenious dyers of *printed* velverets, fuſtians, &c. near Mancheſter, ſome time ſince informed me of their having purchaſed the knowledge of an advantageous method of uſing the bark for this particular kind of dying, and of their having practiſed it with ſo much ſucceſs as to have wholly laid aſide the uſe of weld. This method they afterwards gave me an account of, in conſequence of my offering to repay what it had coſt them; which I did from a deſire to afford the public all poſſible information on this ſubject. Their account is as follows, *viz.*

" In uſing the Quercitron bark, for every four pieces of half-ell velverets, about forty yards long, we take eight pounds of the light coloured bark and put it into a caſk large enough to hold about 70 gallons, open at the top, and provided with a ſpigot and faucet placed about ſix inches from the bottom to draw off the liquor: we fill this caſk with boiling water, ſtir it well, and let it remain upon the bark for three hours or more; and then after the (printed) goods have been well waſhed out of the dying liquor, for the four pieces we put four pounds of Malaga ſumach into a copper nearly filled with water, and with a very little fire under it; in this we put and keep the goods for about one hour, during

which

which the dove or drab colours may be rendered ſufficiently dark by keeping the liquor, at moſt, a little more than blood warm. When the goods are taken out of the ſumach liquor, they muſt be rinced in water; and whilſt this is doing, we draw the clear bark liquor out of the caſk and put it into a copper with as much water as will ſerve to dye the goods conveniently; we then light a fire and gradually bring the liquor to a blood warmth in about an hour, keeping the goods therein till the yellow becomes ſufficiently dark or full, and taking care that the liquor be not made too hot. The goods, being well waſhed after dying in this way, will be found white without branning."

It ought to be remembered, that, according to this method, the ſumach is to be applied ſeparately *before the bark*, inſtead of being applied *after* or *along with it*, as I have juſt recommended in callico printing. How far this method may be preferable to the other for the dying of printed velverets, future experience muſt determine; though certainly that of Meſſrs. H. and ſon ought, on this point, to have great weight even at preſent. In callico printing, however, this method of applying the ſumach and bark has been tried, not only by the experiments which I have made upon a ſmall ſcale, but by thoſe which an ingenious callico printer made ſometime ſince on a larger one, at my deſire, and in both, without affording any reaſon to prefer it over the other.

It can hardly be neceſſary for me to mention here, that the Quercitron yellow produces a green upon an indigo blue, and an orange upon the madder red, in the ſame ways and by the ſame means which enable the weld to produce theſe colours in callico printing. Nor need I mention the advantage which the bark poſſeſſes over weld in this way, by not tarniſhing the madder colours upon pieces where ſuch colours have been previouſly dyed; this advantage being now generally known and acknowledged.

*Of the Uſes of Quercitron Bark, in producing* Topical *Yellow and other Colours,* proſubſtantively, *upon Cotton and Linen.*

By the denomination of *proſubſtantive* topical colours, I mean certain mixtures, in which the colouring matter and the mordant or baſis are combined in a fluid ſtate, fit to be applied *together* by the pencil, block, &c. to linen or cotton, as explained at page 176 of this volume: theſe are what callico printers have uſually named *chymical colours*; an appellation too vague to be retained in a work which aims at preciſion and ſyſtematical arrangement.

Were it poſſible to obtain a ſufficient number of *laſting* and *bright* colours of this kind at a moderate expence, the art of callico printing would ſoon reach the higheſt degree of perfection. Whether ſo many of theſe ever will be diſcovered, as to render topical dying unneceſſary, I know not; but if we cannot obtain all that is deſirable in this reſpect, the art will at leaſt derive benefit from any improvement in the few proſubſubſtantive topical colours now in uſe; and more eſpecially from any addition to their number.

My readers already know that alumine or the earth of alum when diſſolved, eſpecially in the acetous acid, and conveyed into the pores of linen or cotton, is able afterwards to attract to itſelf different adjective colouring matters, applied either by general or by topical dying, ſo as to produce laſting red, yellow, and other colours; and it is much to be regretted that for reaſons which I have endeavoured to explain in other parts of this volume, the ſame mordant will not produce colours equally permanent, when it has been previouſly mixed with the colouring matter, and is afterwards applied (with it) topically to linen or cotton. The difference in this reſpect is indeed very great among the madder colours; thoſe dyed upon an aluminous baſis, applied ſeparately, being always very durable, whilſt thoſe given by proſubſtantive topical application fade and decay very ſpeedily. The difference is however ſo much leſs when colours are produced in theſe different ways from Quercitron bark inſtead of madder, that I can with confidence recommend the bark as affording better and more durable proſubſtantive yellows for topical application, than any thing elſe yet diſcovered. The moſt ſimple yellow of this kind which I have to offer, may be prepared in the following way and proportions, *viz.* For three gallons of proſubſtantive tingent liquor, let three pounds of alum and three ounces of clean chalk be firſt diſſolved in a gallon of hot water, and then add two pounds of ſugar of lead; ſtir this mixture occaſionally during the ſpace of twenty-four or thirty-ſix hours,

 then

then let it remain twelve hours at reſt, and afterwa ds decant and preſerve the clear liquor; this being done, pour ſo much more warm water upon the remaining ſediment, as, after ſtirring and leaving the mixture to ſettle, will afford clear liquor enough to make, when mixed with the former, three quarts of this aluminous mordant or acetite of alumine. Then take not leſs than ſix, nor more than eight, pounds of Quercitron bark properly ground, put this into a tinned copper veſſel, with four or five gallons of clean ſoft water, and make it boil for the ſpace of one hour at leaſt, adding a little more water if at any time the quantity of liquor ſhould not be ſufficient to cover the ſurface of the bark: the liquor having boiled ſufficiently ſhould be taken from the fire, and left undiſturbed for half-an-hour, and then the clear decoction ſhould be poured off through a fine ſieve or canvaſs ſtrainer. This being done, let ſix quarts more of clear water be poured upon the ſame bark, and made to boil ten or fifteen minutes, both having been firſt well ſtirred; and being afterwards left a ſufficient time to ſettle, the clean decoction may then be ſtrained off, and put with the former into a ſhallow wide veſſel to be evaporated by boiling, until what remains, being joined to the three quarts of aluminous mordant before mentioned, and to a ſufficient quantity of gum or paſte for thickening, will barely ſuffice to make three gallons of liquor in the whole. It will be proper however not to add the aluminous mordant until the decoction is ſo far cooled, as to be but little more than blood warm, and theſe being thoroughly mixed by ſtirring, may afterwards be thickened by the gum of Senegal or by gum arabic, if the

the mixture is intended for penciling; or by a paſte made with ſtarch or flour, if it be intended for printing.

Where gum is employed, it will be proper firſt to diſſolve it in water, uſing only what is barely ſufficient to produce a ſolution, leſt a greater quantity of water ſhould increaſe the mixture beyond the quantity of three gallons, for which the portions of bark and aluminous mordant here preſcribed will properly ſuffice, but not for more, without weakening the colour in ſome degree; and for this reaſon it may be ſafeſt to evaporate the decoction rather more than ſeems neceſſary; becauſe, when mixed with the other ingredients, if the whole proves to be leſs than three gallons, the deficiency may be readily ſupplied by a little warm water.

In preparing this mixture however, great care muſt be taken to thicken it only ſo much as may be neceſſary to keep it from running or ſpreading beyond the proper limits; ſince every degree of thickening, beyond this point, will hinder the colouring matter from penetrating ſufficiently into the fibres of the linen or cotton, and thereby render the colour ſuperficial and feeble.

When this profubſtantive mixture (which I ſhall diſtinguiſh as No 1.), after being duly prepared, has been applied to linen or cotton by the pencil or otherwiſe, the pieces ſhould be thoroughly dried by a ſtove heat, and afterwards placed in clean running water, to remove the ſuperfluous colour; and if running water be wanting,

ing, other ſuitable means are to be employed for this purpoſe.

A good lively yellow may be produced in this way, not indeed quite ſo laſting as that obtained when the mordant alone is applied firſt, and the colouring matter afterwards, by topical dying: it will however be able to bear the action of ſun and air, and alſo of ſoap in waſhing, for ſo long a time, as almoſt to deſerve the appellation of a *faſt* colour.

It muſt, however, be obſerved that this yellow, though nearly or quite as high as that given by topical dying with either weld or Quercitron bark, does not prove ſo high and full as is deſirable for this mode of application; ſince colours which are applied by the pencil bear but a ſmall proportion to the others with which they are intermixed, and are therefore required to be more ſtrikingly full that they may not be overlooked; and it is only in this reſpect that the colour obtained from French berries, and called the *berry* yellow, has given any degree of ſatisfaction, it being of all others the moſt fugitive and fallacious. To relieve callico printers from all temptation to uſe a colour which, being fitted only to deceive, ought never to have been uſed, I have made numberleſs trials with the Quercitron bark, joined to almoſt every poſſible mordant or baſis; and of theſe ſome have been attended with ſucceſs, though the means employed in ſeveral of them are either too expenſive or too difficult of application for general uſe, by perſons not verſed in chymical operations. There are others however not liable to theſe objections;
and

and perhaps all things confidered the moft convenient, among the feveral means of raifing the Quercitron yellow, for profubftantive topical application, and at the fame time of increafing its durability, may be found in the nitrate of copper, and the nitrate of lime, added to the mixture No. 1. juft defcribed. It is indeed true, that fome of the folutions of tin produce ftill higher yellows with the Quercitron bark; but they are liable to at leaft two objections, which will be particularly mentioned hereafter.

If copper in fmall pieces be put by a little at a time into a large open glafs veffel, partly filled with fingle aqua fortis, until the acid can diffolve no more of the metal; and if the folution be left open to a free accefs of air, it will foon be wholly converted into blue chryftals, which are what I mean at prefent by the denomination of nitrate of copper. About one pound and a quarter of this falt may be added to the three gallons of profubftantive yellow No. 1. together with four ounces of pure unflacked lime, previoufly mixed with eight ounces of fingle aqua fortis. Clean oyfter-fhells thoroughly burnt will afford the beft lime for this purpofe; which fhould be beaten into powder before it is put into the aqua fortis, to form the nitrate of lime here wanted. This, as well as the nitrate of copper, fhould be added to the decoction of bark before mentioned foon after the aluminous mordant, and before the liquor has been thickened by gum or pafte; and the mixture fhould afterwards be well ftirred, and kept a little more than blood warm for half an hour before the thickening is added.

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The nitrates of copper and of lime joined in this way to the mixture No. 1. will confiderably raife the yellow colour, and alfo enable it, for a longer time, to withftand the action of fun and air; they will alfo enable the colour to bear the action of vinegar and weak acids a little better than it otherwife would, though I do not confider this laft as any teft of the goodnefs of a colour, nor as being a circumftance of any great importance. This profubftantive colour I fhall diftinguifh as No. 2. And confidering that the bark in this way affords a colour full as high, and infinitely more lafting, as well as cheaper, than any which can be obtained from French berries, I think thofe callico printers, if there fhould be any, who may hereafter continue to employ the latter, will fhew themfelves ftrangely unmindful of their own intereft, as well as of their duty to the public, and the credit of their art.

The nitrate of alumine, employed as a mordant with the decoction of bark, produces a profubftantive topical yellow of confiderable durability; but it is apt to acquire too much of a brownifh complexion.

The muriate of alumine, mixed with the decoction of bark, produces in this way, effects very fimilar to thofe of common alum; and this is alfo the cafe where a tartrite of alumine is employed. Alumine diffolved in the pyro ligneous acid, being tried with the bark in this way, produced effects perhaps a little, though but a very little better.

None of the ſolutions of alumine by pot-aſh, ſoda, or ammoniac, ſucceeded as mordants with the bark, for topical application, ſo well as the ſolutions made by acids.

If a decoction be made from ſix or eight pounds of bark, as directed for the preparation No. 1., but without any of the aluminous mordant, and if two pounds of the nitrate of copper, lately deſcribed, be diſſolved therein whilſt a little warm, and the mixture afterwards properly thickened, it will produce, when applied to linen or cotton, a good proſubſtantive *yellowiſh green*, capable of bearing expoſure to ſun and air, and waſhing with ſoap, ſo as almoſt to deſerve the name of a faſt colour. By adding four ounces of lime, mixed with eight ounces of aqua fortis, the colour will be improved; and it may be rendered ſtill more beautiful, and I think a little more laſting, by adding immediately after the nitrate of copper, one pound of ammoniate of copper, made by pouring a pound of the aqua-ammoniæ of the New London Diſpenſatory into a cloſe glaſs veſſel, with a ſufficient quantity of filings, or ſmall bits of copper, and keeping the veſſel cloſely ſtopped until the alkali has combined with as much copper as it can diſſolve, and thus acquired a very beautiful deep blue colour. This yellowiſh green proſubſtantive mixture I ſhall diſtinguiſh as No. 3.; and I believe there are no other means by which a ſimilar colour can be obtained of equal beauty and durability.

The ammoniate of copper alone produces, with the decoction of bark in this way, a greeniſh yellow deſerving of notice.

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The acetate of copper (verdigrife diffolved by vinegar) mixed with a decoction of the bark, and topically applied upon cotton, produces a full brownifh yellow, which however proves not fo lafting as either No. 1. or No. 2.

And the muriate of copper, with the decoction of bark, produces in this way a yellowifh olive, which foon fades upon linen and cotton.

It has already been noticed, that cottons impregnated with the oxyds or folutions of tin as a bafis of colour, and then dyed with Quercitron bark, imbibed colours highly beautiful, and capable of refifting the action of boiling foap fuds as well as of ftrong acids; but at the fame time highly fugitive, when expofed to the fun and open air, a defect which it would have been reafonable to expect even in a greater degree, where the tin bafis, inftead of being previoufly fixed in the cotton, was firft united to the colouring matter, and afterwards applied therewith profubftantively. A contrary effect however really takes place in fome degree.

If a decoction be made from fix pounds of bark, as for the preparation No. 1. (but without any aluminous mordant,) and one pound, or one pound and a quarter of the murio-fulphate of tin, fo often mentioned, be added, the mixture being afterwards well ftirred and properly thickened, will afford a very bright and full profubftantive yellow, liable indeed to become a little brown by expofure to the fun and air; but at the fame time of confiderable durability, and able to withftand the action of acids or boiling

foap

ſoap ſuds. It muſt however be remembered, that the oxyd of tin has a ſtronger attraction than that of iron, for moſt vegetable colouring matters, and eſpecially for that of madder; and therefore when proſubſtantive colouring mixtures, containing ſolutions of tin like that juſt mentioned, are applied *cloſely* upon madder purples or blacks, (made ſuch by the oxyd of iron,) theſe latter colours will become red where-ever they are touched by theſe mixtures. And for this reaſon, whenever a proſubſtantive yellow is wanted to be laid immediately upon the edge of a dark madder colour, (which is moſt frequently the caſe,) it will be proper to employ the preparation, No. 2.

The nitro-muriate of tin, made with about two parts of nitric to one of muriatic acid, produces in this way, with the decoction of bark, a very high lively yellow, capable of reſiſting ſtrong acids, boiling ſoap, &c. but very liable to become brown by expoſure to the ſun and air; an effect which I found lemon juice had the power of preventing, in ſpots which, for another purpoſe, had been wetted therewith. Olive oil applied ſo as to cover yellow ſpots or figures produced by the decoction of bark and nitro-muriate of tin, appeared to have no effect in defending or preſerving the colour from injury by expoſure to the ſun and air; and linſeed oil applied in the ſame way did manifeſt harm, the ſpots covered by it having acquired a blackiſh hue after a few weeks expoſure to the weather. Theſe joined to other facts will hereafter help us to ſome uſeful concluſions. Muriate of tin with the decoction of bark, applied proſub-

ſtantively

ſtantively to cotton, affords a very lively delicate yellow; but it is leſs capable than the former of reſiſting the action of ſoap, and of acids; nor does it long bear expoſure to ſun and air. This is alſo true of the yellow produced in this way by the tartrite of tin and decoction of bark.

The ſulphate of tin mixed with a decoction of the bark, and applied in this way to cotton, gives a kind of cinnamon colour, ſufficiently laſting. Phoſphate of tin produced only a dull browniſh yellow with the decoction of bark. Tin diſſolved by cream of tartar, mixed with twice its weight of muriatic acid, produced, with a decoction of the bark, proſubſtantively upon cotton, a very lively ſtrong yellow, of conſiderable durability. I have tried many other ſolutions and combinations of tin with the bark, and indeed almoſt every one which it is poſſible to form, but without any effects better than thoſe which may be obtained from the mixtures already mentioned. My readers therefore will not require a particular account of them, eſpecially as the uſe of all proſubſtantive yellows which contain ſolutions of tin, though they afford by much the higheſt and moſt beautiful colours, muſt prove very limited by reaſon of their effect of reddening the dark madder colours.

It has been already obſerved, that the decoction of bark with the nitrates of copper and lime, and the ammoniate of copper, produces a good proſubſtantive yellowiſh green; and this may be rendered darker and fuller by ſuperadding a portion of the logwood blue. Two callico printers have aſſured me that by combining the bark and logwood with particular ſolutions or preparations of copper, they had been able to obtain a green for topical application ſo faſt, as to bear the proceſs of field bleaching without injury; and one of them declared, that it was by adding to a decoction of bark and logwood boiled together, a ſuitable portion of ſulphate of copper and of verdigriſe, with a little pot-aſh; this laſt, and the efferveſcence which it produced, he ſeemed to think of importance. As yet, however, my endeavours to produce a green fully anſwering this deſcription have not ſucceeded, though they have ſeveral times been attended with ſuch appearances of ſucceſs, as will induce me to make farther trials. Thoſe hitherto made ſeemed to have failed principally by the want of ſufficient permanency in the blue or logwood part of the green colour. A great number of experiments, made at leaſt ſeventeen years ago, taught me, that a beautiful proſubſtantive blue, capable of reſiſting ſun and air for a conſiderable time, when applied topically upon linen or cotton, might be obtained by combining the colouring matter of logwood with the ſulphate of copper and the ammoniate of copper.

Six pounds of logwood boiled with water, as directed for the Quercitron bark, will afford colouring matter enough for three gallons of liquor when thickened; to this decoction whilſt warm, and before it is thickened, two pounds of blue vitriol may be added, and as ſoon as it is diſſolved, two pounds of ammoniate of copper, made as already explained; and the liquor after being well ſtirred may be thickened and applied as uſual. By ſubſtituting the nitrate of copper for the ſulphate of that metal, a dark blue may be produced, equally durable but not ſo lively and beautiful; though I think this laſt rather preferable to the other, for the purpoſe of forming a proſubſtantive green with the Quercitron yellow; for which purpoſe it will be ſufficient to mix as much of this logwood blue with the yellowiſh green, No. 3, as may ſerve to produce the particular ſhade of colour wanted; or the logwood blue may be added to the yellow, No. 2, for the like purpoſe. And though the greens produced in theſe ways are not ſo laſting as to deſerve to be called faſt colours, they are as good as any which I have yet been able to produce by uniting the Quercitron and logwood colouring matters, and indeed are ſuch as it may be often convenient to employ.

If a ſuitable portion of ſtrong iron liquor be mixed with a decoction of the Quercitron bark made as already directed, and the mixture be properly thickened, a proſubſtantive drab colour of ſome durability for topical application, may be produced; and this mixed with an equal portion of the preparations No. 1 or No. 2, will produce an olive. If a ſolution of iron, by a diluted muriatic acid, or by a diluted nitric acid, be employed for this purpoſe inſtead of iron liquor, it will produce colours a little more laſting; but theſe ſolutions ſhould be employed ſparingly, that they may not hurt the texture of the linen or cotton to which they are intended to be applied.

Zinc, diſſolved by the ſulphuric, the nitric, and the muriatic acids, ſeparately, and mixed with

with the decoction of bark, produces browniſh yellow colours of different ſhades, but none of them ſufficiently laſting when topically applied upon linen or cotton.

Mercury, diſſolved by the different acids, produced with the decoctions of the bark different brown and yellowiſh brown colours, but none of them more durable in this way, than thoſe afforded by different ſolutions of zinc.

The nitro-muriate of Platina, mixed with a ſuitable portion of decoction of bark, and topically applied either to linen or cotton, produces ſtrong full-bodied ſnuff colours, which bear the action of acids and of the ſun and air.

The nitrate of ſilver, mixed with a decoction of the bark, produces by topical application upon linen or cotton, ſtrong dark brown and cinnamon colours of conſiderable durability.

The nitrate of lead, with the colouring matter of bark, produces in this way a drab colour of equal durability.

The nitrate of biſmuth, with a decoction of the bark, produces a very full and ſtrong browniſh yellow, which would prove laſting, were it not liable to become almoſt black by alkaline ſulphures, by ſulphurated hydrogenous gas, and ſometimes by the action even of common ſoap.

The muriate of biſmuth produces a drab colour with the bark, and the ſulphate of that metal a yellow; but neither of theſe are laſting upon linen or cotton.

The nitro-muriate of antimony produces with the bark, a kind of ſnuff colour of ſome durability on linen and cotton; and different ſhades of brown were produced in this way by the nitrate and the muriate of cobalt with the bark, which however ſoon faded by expoſure to ſun and air.

In giving this account of the properties and uſes of Quercitron bark, I have had before me notes of ſeveral thouſands of experiments made therewith, in almoſt all poſſible ways, and with almoſt all poſſible chymical agents. But as a detail of their effects would more than exhauſt the patience of any reader, I ſhall content myſelf with ſtating as I have here done, the reſults of thoſe which ſeem moſt likely to prove uſeful; and probably what I have already ſtated is more than enough on this ſubject. I have however thought it incumbent on me to omit nothing in any degree likely to afford uſeful information reſpecting a *new dying drug*, firſt brought into uſe by my exertions, and which without them would probably have remained unknown as a dying drug for ages to come:— a drug which has already produced important benefits, eſpecially to the art of callico-printing in Great Britain; and is likely hereafter to benefit other European nations, as well as the United States of America, in an eminent degree. The conſumption has indeed hitherto been ſmall, compared to the probable future increaſe; but it has been large

conſidering

confidering the fhort time fince its properties were firft made known, and the immenfe difficulties which attend the introduction of all new dying drugs: it appearing by the act of the 13th and 14th of Charles II. ch. 2., that nearly one hundred years had elapfed before "the ingenious induftry of modern times had taught the "dyers of England the art of fixing the colours "made of logwood." And though indigo, the moft valuable of all dying drugs, had been known in Afia for at leaft two thoufand years, the ufe of it was either prohibited or reftrained for a confiderable time in different European countries, from an erroneous belief that its colour was fugitive: fo difficult has it always been found to bring dying drugs into their *due eftimation*. But though the Quercitron bark has been employed only for fo fhort a time, I flatter myfelf that the account which I now offer of its properties and ufes, will prove much more complete than any yet given of the properties and ufes of any other dying drug, even among thofe which have been known for many ages.

# CHAP. XIII.

## *Of the Properties and Uses of Juglans Alba, or American Hiccory; of the Weld Plant, Fustic, and other Vegetables, affording yellow adjective Colouring Matters.*

"La couleur jaune est celle que la nature a repandue "partout avec la plus grande profusion,—elle peut etre "regardée de droit comme couleur primitive."

Annales de Chymic. tom. xvii.

ARTICLE 1st. *American hiccory*:—Not only the bark but the green leaves and the rinds of the nuts of this tree, yield an adjective colouring matter so very similar to that of the Quercitron bark, that all the instructions which I have given respecting the latter, will be found applicable to the hiccory; allowing only for the difference between their respective proportions of colouring matter; that of the hiccory bark being about one-third less than what is contained in a like quantity of Quercitron bark. It is this difference, joined to the greater difficulty and expence of grinding the hiccory bark, on account of its great hardness and toughness, which has enabled the Quercitron bark almost wholly to supersede the use of the hiccory; for, excepting the prosubstantive topical yellows, for which it does not seem to answer quite so well, there is perhaps no purpose to which the colouring matter of the hiccory may not be applied with effects as good as those resulting from the Quer-

Quercitron bark; and I have ſometimes thought, that ſome of the *varieties* of this tree might be preferable to the Quercitron bark, for imitating the greeniſh lemon yellow of the weld plant on wool, with an aluminous baſis. I ſay of ſome of the *varities*, becauſe there certainly are conſiderable differences between the ſhades of yellow produced by the ſeveral varieties of the hiccory tree; that for inſtance which Marſhall calls juglans alba acuminata, produces a clear lemon yellow, whilſt the juglans alba minima produces a fuller, though not a very bright, yellow; and the juglans alba odorata a yellow, which is very full and alſo very lively.

Generally however the hiccory bark employed in the way of callico printing, or topical dying upon linen and cotton, produces colours very ſimilar to thoſe of the Quercitron bark, both upon the aluminous and ferruginous baſes, and with no greater degree of ſtain or diſcolouration upon the parts intended to be kept white. This alſo is one of the vegetable colouring matters, of which the uſe has been excluſively ſecured to me for a term of years by an act of parliament.

Art. 2. The *weld plant* (reſeda luteola Lin.) grows wild, as well as by cultivation, in many parts of Europe; the cultivated plants are however ſmaller than the wild, and more abundant in colouring matter. There are ſome varieties of this ſpecies; two or three years ſince a little parcel was put into my hands, which had been brought from Hamburgh, and of which the ſtalks were not more than a fourth part ſo high or ſo large as thoſe of the weld raiſed in this kingdom. I did not however find much ſuperiority in the quality of its colouring matter, though in quantity it yielded at leaſt four times as much as an equal weight of either Engliſh or French weld; and the price, as I underſtood, was proportionably greater. This variety of the weld, according to my information, grows and is made uſe of in ſeveral parts of Germany. I have already noticed all the particulars of any importance in which the colouring matter of weld differs from that of the Quercitron bark, and have therefore but little to add reſpecting the former; both affording adjective colours of the ſame ſhades by the ſame baſis or mordants, with only a few exceptions, of which the greateſt part have been already mentioned in treating of the bark.

Weld requires the growth of nearly two ſummers before it comes to maturity; and the crop is beſides liable to fail from ſo many cauſes, that it cannot be a deſirable object of agriculture, eſpecially in Great Britain. It moreover occupies nearly one hundred times more ſpace than a quantity of bark, capable of yielding an equal portion of colouring matter, and of dying an equal weight of cloth; a circumſtance which compels the dyer and callico-printer to extract the colouring matter by previous boiling; ſince if the weld were put into the dying veſſel, as is done with the bark, there would be no room for any thing elſe. It alſo renders the tranſportation into Scotland and the northern counties of England, (where it will not grow,) ſo expenſive, that the callico-printers of Lancaſhire, Carliſle, Glaſgow, &c. could not have exerciſed their art, either

either ſo advantageouſly or ſo extenſively as they have done for ſome years paſt, had not the Quercitron bark enabled them almoſt wholly to lay aſide the uſe of weld.

That the colouring matter of weld may be more readily extracted; the woollen-dyers frequently add a little ſtale urine, or lime and pot-aſh to the water in which it is boiled: and in preparing wool or cloth, by impregnating it with the aluminous baſis, they commonly employ three or four ounces of alum and one of tartar, for each pound of the woollen cloth. Tartar is ſuppoſed to render the yellow colour a little more clear and lively. I have good reaſon however to believe, that it may, without inconvenience, be wholly omitted in dying with weld, as well as with the bark, excepting only for thoſe delicately bright and greeniſh ſhades, for which it is now uſual to employ a portion of the nitro-muriate of tin (dyers ſpirits) along with alum in boiling or preparing the wool and cloth; and for which the uſe of tartar will prove highly beneficial.

In topical dying or callico printing, very little leſs than the heat of boiling water will ſuffice to fix the colouring matter of weld, and the parts wanted to be kept white, are then ſo much ſtained by it, and this ſtain is ſo difficult to remove, that during the damp cloudy weather which generally prevails in winter, four or five weeks expoſure on the graſs will hardly prove ſufficient for that purpoſe. This is a ſerious inconvenience which does not attend the uſe of the bark.

Weld

Weld alfo produces another bad effect when employed for topical dying upon linens or cottons, which have previoufly received a courfe of madder colours; for in this cafe the *weld yellow* by a particular affinity applies and fixes itfelf upon thefe colours fo copioufly as to change their appearance, and tarnifh their luftre greatly; and this is another defect from which the bark is nearly, if not wholly, exempt.

By the act of the thirteenth of his prefent Majefty, ch. 77, the fum of 2000l. was granted to Dr. Richard Williams as a reward for his invention of a faft green and yellow dye on cotton, yarn, and thread. This fuppofed faft dye was given with weld by the help of a mordant; the compofition of which (that foreigners might not enjoy the benefit of it) Dr. Williams was permitted to conceal, and to fupply the cotton and thread dyers therewith at a certain price. I have however reafon to believe, that it was either a folution of tin alone, or of tin and bifmuth, which enabled the weld yellow, as it enables that of the bark, to bear the action of acids and of boiling foap-fuds, though unable to bear the action of fun and air. This defect, however, was not readily difcoverable by the method which Dr. Williams employed to obtain a favourable teftimony from the dyers on this fubject. His method was that of weaving the dyed yarn into pocket handkerchiefs, and giving them to be worn in the pockets of thofe who were afterwards to atteft the goodnefs of his dye; and as handkerchiefs inclofed in a pocket are not expofed to the fun and air, the defect in queftion was not perceived until fome time after

after the reward had been paid for a ſuppoſed invention of no value, and of which, I believe, no uſe is now made.

Art. 3d. Rhus cotinus Lin. or venice ſumach, improperly called *young* fuſtic, is a ſhrub growing principally in Italy, and the South of France; whence the root, as well as the ſtem or trunk of the ſhrub, deprived of the bark, are brought and employed (chipped) for dying a full high yellow, approaching to the orange, upon wool or cloth prepared with the nitro-muriate of tin, or dyers ſpirit. But the colour obtained by theſe means always proves extremely fugitive; and it is beſides neither ſo bright nor ſo high as the yellow which may be more cheaply obtained from the Quercitron bark, and the muriate or nitro-muriate of tin, with alum. Four pounds of the rhus cotinus chipped, afford no more colour than one pound of the Quercitron bark.

Art. 4th. Morus tinctoria Lin. or fuſtic, called improperly *Old Fuſtic* by the Engliſh, and Bois Jaune by the French, is a large tree growing naturally in Jamaica, Porto Rico, Tobago, and almoſt all the other Weſt-India iſlands; its wood is of the colour of ſulphur, and has within little more than a century, been brought into general uſe as a dying drug, though the yellow colour which it affords with an aluminous baſis is neither high nor bright; it has however the advantage of being durable, and of not being thrown down or made latent by acids ſo much as the weld and Quercitron yellows; and for this reaſon it is now very commonly employed (chipped

(chipped or ground) in dying Saxon greens upon cloth, with the ſulphate of indigo, as mentioned at pages 337 and 338; the muddineſs of its yellow being of but little detriment to the full dark greens moſt frequently dyed with it in this way.

It is alſo very much employed for dying drab colours upon cloth, and eſpecially on cotton-velvets, fuſtians, &c. with an iron baſis, and olives with a mixture of this and of the aluminous baſis, as has been mentioned in the preceding chapter, where ſo much is ſaid reſpecting the means and modes of employing the bark, which may be applied with equal advantage to the wood in queſtion, that I ſhall add but little more upon this ſubject. Four pounds of this wood chipped, yield about as much colouring matter as one pound of the Quercitron bark; and allowing for this difference of quantity, it may be employed for general dying with the ſeveral mordants or baſes propoſed for the bark; remembering always that the yellow colour which it affords, can never be made to acquire any thing like an equal degree of clearneſs and brightneſs with that of the bark or of the weld; and for this, with ſome other reaſons, it is not likely to be ever employed in callico printing.

I am not yet able to aſcertain whence the word fuſtic was derived to our language. Venice ſumach appears to have been long diſtinguiſhed in France by the name of *Fuſtet*, and I ſuſpect that our dyers with the wood introduced the name, and changed it to *Fuſtic*; ſuch changes having

having frequently happened in other cafes. The morus tinctoria being afterwards brought from America, and alfo employed for dying yellow, and being deftitute of a name, appears to have likewife acquired that of fuftic; and a confufion having arifen by thus giving the fame name to two different fpecies of wood, a diftinction was improperly created by calling that of the venice fumach, *Young* Fuftic, (as being manifeftly the wood of a fmall fhrub,) and that of the morus tinctoria, (which is always imported in the form of large logs or blocks) *Old* Fuftic. At what time thefe epithets were firft applied, to create this diftinction, I have not difcovered; but they muft have been in general ufe, at leaft 130 years ago; becaufe Sir William Petty, in an account "of the Common Practices of Dying," which he gave to the Royal Society when firft inftituted, mentions Venice fumach under the name of "*Young* Fuftic," and the morus tinctoria under that of "*Old*," as being their common and appropriated names. In this way, however, many perfons have been mifled fo far as to conclude that two very diftinct dying drugs (the one a fmall *European fhrub* of the fumach kind, and the other a large *American tree* of the mulberry kind) were the fame, or differing from each other only in *point of age*. The French have indeed avoided this fource of error, by leaving the Venice fumach to bear exclufively the name of *Fuftet*, and giving that of Bois Jaune or yellow wood to the Morus Tinctoria; and perhaps it might be well for us even now to call the latter *yellow wood*, or *dyers mulberry*, in order to avoid the error in queftion, were it not that what is called young

fuftic

fuſtic is likely ſoon to fall into ſuch abſolute diſuſe as to render any change unneceſſary. The wood known in England by the name of green ebony, poſſeſſes a ſpecies of yellow colouring matter very ſimilar to that of the morus tinctoria in dying, and is ſometimes employed in its ſtead.

Art. 5th. The common ſumach of Spain, Portugal, and other parts of Europe (rhus coriaria Lin.) affords a yellow dye with the aluminous baſis; but ſo pale and of ſo little brightneſs, that it is very rarely employed for the purpoſe of giving a yellow colour only; it however poſſeſſes another ſpecies of colouring matter ſimilar in moſt reſpects to that contained in galls, and therefore capable of dying black with iron and the ſolutions of that metal: this ſpecies of colouring matter, and the application thereof, upon wool and cotton, will be treated of in their proper place. The principal uſes of ſumach in callico printing have been already noticed in the preceding chapter. Uſed by itſelf in this way, it ſtains the white parts very durably; but uſed with the Quercitron bark it is thereby hindered from giving any ſtain, and at the ſame time it obviates that which the bark might otherwiſe communicate.

Art. 6th. The unripe berries of the rhamnus infectorius of Linnæus, are called French berries, and chiefly employed for preparing a lively but very fugitive yellow for topical application in callico printing. Cotton printed with the aluminous mordant, and dyed with theſe berries, inſtead of weld or Quercitron bark, receives

receives a full bright yellow; but in this and every other way it fades ſo ſpeedily, that the uſe thereof is a groſs impoſition, which the public ought not to tolerate, whilſt there are other means of giving ſuch durable yellows as will not deceive or diſappoint the wearers. There is a particular ſpecies or variety of the rhamnus infectorius growing in Candia and other parts of the Levant, yielding berries larger than thoſe brought from the ſouth of France; they are diſtinguiſhed by the name of Turkey berries, and preferred to the French, though the colours of both are equally fugitive.

Art. 7th. Saw-wort, ſerratula tinctoria Lin. affords a good ſubſtitute for weld in dying upon the aluminous baſis, with which it communicates a bright lemon yellow of conſiderable durability. The common preparation with alum and tartar, is to be employed for wool and cloth; or if a brighter colour be wanted, the preparation may be given with nitro-muriate of tin, (dyers ſpirit,) and half as much tartar.

For giving a very inferior yellow upon coarſer woollens, the dyers broom (geniſta tinctoria Lin.) is ſometimes employed, with the common preparation of alum and tartar.

All the five ſpecies of erica or heath growing on this iſland, are, I believe, capable of affording yellows much like thoſe obtained from the dyers broom—their colours may indeed be raiſed and brightened by the ſolutions of tin, but when this has been done, I have always ſeen them prove fugitive. This I have alſo found to be the caſe of the yellow dyed with the bark and ſhoots of the Lombardy poplar, populus pyramidalis, recommended by Monſ. d'Ambourney. He ſtates the expence of *materials* for preparing and dying ſixty pounds of wool with the young ſhoots of Lombardy poplar, and the tin baſis, to be eighteen livres, which is more than double what it would coſt to produce a much better colour with the Quercitron bark, as I have already mentioned in the proper place.

According to Scheffer and Bergman, the leaves of the ſweet willow, (ſalix pentandria,) gathered about the end of Auguſt or beginning of September, and dried in the ſhade, afford, if boiled with about 1-30th of pot-aſh, a fine yellow colour to wool, ſilk, and thread, impregnated with the aluminous baſis. I have, however, made no trial with them as yet.

Art. 8th. The American golden rod, ſolidago canadenſis Lin. affords very beautiful yellows to wool, ſilk, and cotton upon the aluminous baſis. Hellot ſeems to have been the firſt who attempted, though without ſucceſs, to introduce this plant into general uſe as a yellow dying drug; and Meſſrs. Gaad and Succow have ſince made the like attempts with no better ſucceſs; though I can affirm from the reſults of many trials, that it would prove a very advantageous ſubſtitute for the weld in callico printing; the colour which it affords in this way, to parts printed with the aluminous mordant, proves highly beautiful, and the ſtain or diſcolouration produced upon the unprinted parts,

is

is much leſs conſiderable and much more eaſily diſcharged than that of weld. The plant (golden rod) is alſo more rich in colour, and capable of being raiſed with great eaſe. It grows naturally in abundance, almoſt every where, between Carolina and Hudſon's Bay.

Kalm ſays, that the three-leaved Hellebore, (helleborus trifolius,) called Tiſſavoyanne jaune by the French in Canada, is there uſed by the Indians in giving a fine yellow colour to ſeveral kinds of work, which they make of prepared ſkins; and that the French having learned this from them, dye wool and other things yellow with this plant. Beſides theſe there are many other vegetables capable of affording adjective yellow colours, both with the aluminous baſis and that of tin, particularly the ſeeds of purple trefoil, lucerne, and fenugreek, the flowers of French marygold, the chamomile, (anthemis tinctoria,) the aſh, (fraxinus excelſor,) the fumitory, (fumaria officinalis,) with ſeveral others which need not be named, as not being likely ever to come into uſe. There is indeed ſo much difficulty in always producing the exact ſhades of colour which dyers are required to imitate, that the uſe of *various* materials for obtaining *ſimilar* effects muſt prove highly inconvenient. A few drugs occupying but little ſpace, rich in colouring matters, and capable of being always obtained as well as extenſively applied, by ſaddening and otherwiſe varying their reſpective colours, are what the dyers moſt need: by being conſtantly occupied with a few ſuch drugs, they acquire that degree of dexterity and certainty in

 uſing

uſing them, which alone can prevent diſappointment in the nice operations of this art.— Such a drug is the Quercitron bark.

Having thus noticed, as far as ſeemed expedient, the different adjective yellows, I ſhall in my next volume proceed firſt to the reds, and afterwards to the other remaining adjective colours.

# APPENDIX.

WHAT I have mentioned refpecting indigo in the former part of this volume, was printed in the beginning of the year 1792. I did not at that time know of an account, which Dr. Roxburgh had then very lately addreffed to the Court of Directors of the Eaft-India Company, of a new fpecies of nerium, (rofe bay,) and of a procefs for manufacturing indigo from its leaves, which has fince been publifhed in Mr. Dalrymple's Oriental Repertory.

Subfequent to the time when that account was written, fo many facts, the refult of numerous experiments and much inquiry, came to the knowledge of Dr. Roxburgh refpecting the tree, the procefs for preparing the indigo, its quality, &c. that he thought a more complete defcription thereof to be neceffary, efpecially as the incomparable beauty and fuperior excellence of the indigo fo obtained, appeared to render it an object highly interefting; and as there were already fome plantations of the nerium in great forwardnefs in Bengal, raifed from feeds which he had fent thither in the years 1790 and 1791, from the Rajamundry Circar. Such a defcription was accordingly prepared by Dr.

Roxburgh, with the addition of " a *second* part, " containing a brief account of the result of " various experiments made with a view to " throw some light on the theory of that beau- " tiful production (indigo); with an appendix " containing a botanical description, &c. of a " *second* new indigo plant; the whole illustrated " with necessary drawings, and addressed to the " Hon. Sir Charles Oakly, Governor and Pre- " sident in Council, &c. at Fort St. George, " to be transmitted to the Honourable Court of " Directors of the United East India Company, " and committed to their protection, with a " view to encourage a more extensive cultiva- " tion of those plants which yield the best " indigo, and to improve the manufacture " thereof."

The papers containing these descriptions and accounts having been put into my hands at the India House, and reason having been given me to believe that, by publishing their contents, I might promote the views as well of the author as of the Court of Directors, I have made, and shall here subjoin an abstract of the more interesting parts thereof.

Dr. Roxburgh observes, that St. Helena and the West-India Islands, contain a great abundance of soil just suited to the nerium tinctorium, *i. e.* hills and the lower regions of mountains where little else is found than rocks, stones, and barren waste lands, such being the soil and situation in which he has always found it growing in India. " One of the circumstances, says Dr. Roxburgh, that have lately come to my knowledge

knowledge refpecting this tree is, that the natives of the Vizagapatam and Ganjam diftricts, and of fome parts of the Carnatic, are acquainted with the property of its leaves: Dr. Patrick Ruffel writes me from England, that amongft the papers of a moft worthy fenfible man, an old college companion of my own, the late Mr. George Campbell, (who was Surgeon on this eftablifhment, and died of wounds he received in the action between Col. Bailey and Hyder Ally in 1780,) there was found an account of the tree, and of the fact that the natives made indigo from its leaves, which was wholly unknown to me when I firft wrote on the fubject."

Dr. Roxburgh defcribes the nerium tinctorium, or tfhit ancalloo of the Hindoos, as a tree of the middle fize, agreeing perfectly in its botanical characters with the nerium of the Linnæan Sexual fyftem, and from the quality of its leaves, fays he, "I have called it nerium tinctorium, dyers rofe bay; for to me it feems a new fpecies, approaching neareft to the nerium antidyfentericum, which yields the coneffi bark of our materia medica: they are both natives of the lower regions of thofe mountains which bound the Rajamundry Circar on the north-fide, and are fo much alike, the nectarium excepted, that without a tolerable knowledge of both, the one may be miftaken for the other. The trunk of the nerium tinctorium is irregular in fhape, being when old from one and a half to two feet in diameter, and from eleven to fifteen feet up to the branches. The bark when old is fcabrous, but when young, ſmooth, and aſh-coloured. The wood is remarkably white and cloſe grained; in appearance reſembling ivory; the leaves when full grown are from ſix to ten inches long, and from three to four broad; they are numerous, oppoſite, ſhort petioled, oval, pointed, pretty ſmooth, and of an intire pale green. The nectary which is wanting in the nerium antidyſentericum, has many ramous white filaments crowning the mouth of the tube of the corol.

This tree alſo grows plentifully throughout the Carnatic, and in every part of the Circars, where there are hills or mountains, being an extent of above 1000 miles in length. It contains a milky juice, chiefly in the tender branches and young leaves, which flows out on their being wounded. Near inhabited places, it is ſo often cut for fire-wood, that in ſuch ſituations it is always found in the ſtate of a very ſmall tree or a large buſh. To make it yield a large ſupply of the beſt leaves for producing indigo, it ſhould be kept low, as is done with the mulberry plantations for feeding ſilk-worms, and, like them, the more it is cut down, the more will it increaſe; as many ſhoots iſſue from the old ſtumps, which in the ſpace of one year grow to various heights from one to ten feet, according to the nature of the ſoil and ſeaſon: The tree caſts its leaves about the beginning of, or during the cold ſeaſon. In March and the beginning of April, the young leaves firſt make their appearance, together with the flowers; by the end of April thoſe which firſt unfolded, will have attained their full ſize; and this I have found to be the proper time for beginning to gather the leaves for the making of Indigo; about this time alſo it ceaſes flowering, and many of the ſeed veſſels are perfectly formed, though the ſeeds are not ripe until January or February. The leaves of this tree differ moſt eſſentially from thoſe of the common indigo plant in not yielding their colour to *cold* water. I have tried every method which I could think of, and with various kinds of water, yet could never with cold water procure more than a very ſmall proportion of a hard, black, flinty ſubſtance, which did not deſerve the name of indigo; it burns very difficultly, with a white ſmoke, leaving dark coloured aſhes; whereas that which is made with hot water burns moſt readily with a moſt beautifully deep violet-coloured ſmoke, and a ſtrong peculiar ſmell, leaving fine white aſhes; but by hot water the colour is readily extracted; for this operation however, works, very different from thoſe by which common indigo is made, are requiſite.

The moſt eſſential part of the operation conſiſts in applying a ſufficiency of heat at the leaſt expence; for in general I have found that the price of fuel was nearly equal to every other charge. By the ſcalding proceſs I have always, on a ſmall ſcale, made from the common indigo plant, better indigo than I could by fermentation, and in one-fourth of the time; and what is alſo of great importance, without the ſmalleſt degree of the pernicious effluvia which attend the manufacture of indigo by fermentation; and moreover the twigs and leaves themſelves of the indigo plant burn fiercely, after having been well dried, and will carry on the operation without requiring any great addition of other fuel. But the works for the nerium have not this advantage, as the *leaves only* are ſcalded. In my firſt experiments in 1789, I uſed the common earthen pots of the country to ſcald the leaves, but for many obvious reaſons large copper veſſels are preferable; they may eaſily be made of any ſize, of ſheathing copper rivetted together and ſoldered. I conceive that ten or twelve feet from the fore part, where the ſcupper is fixed, to the back part, are as much as one fire can act upon; and that five or ſix feet the other way are ſufficient: the depth ought not to be more than two feet, for fear of ſcalding the leaves near the bottom before thoſe near the top are done ſufficiently. The agitation-vat may be built of brick or lime, as is uſual for making the common fermented indigo; but it ſhould never be more than three feet in depth. In the ſequel, it will appear that the blue colour of indigo is derived from the air; it is therefore neceſſary to make the agitation-vat or ciſtern very broad, and always ſhallow, eighteen or twenty inches of liquor in depth being as much as ever ſhould be allowed; the other eighteen or ſixteen inches above the liquor may be called the border, and will not require to be very ſtrong, its uſe being only to prevent the liquor from ſplaſhing over during the agitation. At the edge of this agitation-vat may be built a ſmall ciſtern, to make and contain lime water; and it ſhould be ſo built as to exclude the air, if poſſible, this having a bad effect on lime.

It is proper that the ſurface of the liquor be gently agitated by the wind, while the fæcula is preci-

precipitating, as it will prevent the formation of the violet or copper-coloured fcum, which fhould not be allowed to fubfift; becaufe it hinders in a great meafure that free abforption of the colouring principle, which is derived from the air of the atmofphere, (probably affifted by the contact of light,) and not from the plant itfelf; it being only the *bafe* of the commodity which the leaves yield. The place however fhould be free from duft. Another fmall ciftern or receptacle for drawing off and receiving the fæcula (blue precipitate) is very convenient; in this it will fettle at the bottom; and even then much of the mother liquor may ftill be drawn off by fcuppers, which will render the draining, while in the bags, much lefs tedious. The bottom ought to flope towards the centre, where a fmall excavation fhould be made for taking up the remaining fæcula, and for allowing fand and other heavy impurities to fettle therein. Over this fmall ciftern the draining bags may be hung, until the liquor runs clear from them.

In the month of April the leaves begin to be fit for making indigo; and in May and June I have found them yield a better colour than in any other month. About the end of Auguft the plant ceafes to grow for the feafon, and the leaves acquire a yellowifh rufty colour, and fall off gradually, without being fucceeded by others *generally* until the next feafon: fo that indigo can be made only during four or five months in a year with the plants which grow *fpontaneoufly* in this part of India. The leaves of the plants raifed from feed in my garden, did not yield colour till they were upwards of two years old; and

and then in a ſmall proportion only, and of an inferior quality, compared to that of the *old* plants growing *wild.* If the leaves be picked and the beſt only taken, the indigo will be more beautiful than when they are taken promiſcuouſly together with the extremities of the ſhoots, which will be too young, while leaves on the lowermoſt branches will be too old. I never could extract any thing like indigo from the tender ſhoots of this plant, when deprived of their leaves, though the twigs of the common indigo plants, without leaves, afford indigo readily; but of an inferior quality to that which the leaves of this plant *alone* afford. The leaves of the nerium give indigo not only when freſh gathered, but even when wilted and almoſt dried; they yield, however, the beſt indigo in a middle ſtate, after being kept a day or two: when they are conſiderably wilted, the indigo is of a worſe quality; and when dried, they afford only a dirty brown colour; though the leaves of the common indigo plant bear drying and keeping without any detriment to the indigo which they produce; and it is the practice in many parts of India to dry them before the indigo is extracted: in this reſpect, and in that of not yielding their colour, by cold infuſion, the nerium leaves differ eſſentially from thoſe of the indigofera. The nerium leaves collected the preceding day, are put in a copper, ſo as nearly to fill it without preſſing, and the copper is then filled with water till within two or three inches of the top, this ſpace being neceſſary on account of the expanſion produced by heat. Hard ſpring-water is to be preferred, as contributing to increaſe the quantity of indigo, as

well

well as to improve its quality. The fire is then lighted and kept briſkly up till the liquor acquires a deep green colour, when viewed in the veſſel; though if taken out and poured from one veſſel into another, the ſtream will appear of a pale bright greeniſh yellow: the leaves will then begin to be of a yellowiſh colour, and the heat of the liquor about 150 or 160 degrees of Farenheit's thermometer; little dependance can be placed on the violet or copper coloured ſcum, as the leaves muſt be conſtantly moved about, and turned up and down, that they may be equally ſcalded. This agitation alſo tends to expel the fixed air, (carbonic acid gaz,) by the expulſion of which the operation is much forwarded. The fire muſt be withdrawn a little before the liquor affords theſe appearances; and all the different coppers, whoſe liquor is to be let into the ſame agitation-vat, ſhould be ready or in equal forwardneſs at the ſame time, that the liquor may be drawn off at once. In doing this it ſhould be paſſed through a hair cloth, to ſeparate every part of the leaves from it: as ſoon as the whole is run off, it is to be agitated, while hot, in the common way for a few minutes, (ſay from five to twenty,) which will generally produce a ſufficient granulation. About one 75th part of ſtrong pure lime-water is then to be let in (the liquor being ſtill hot) from the lime-water ciſtern, which requires only to be ſufficiently mixed with the liquor to produce ſpeedily a very large grain, which ſoon precipitates; the ſupernatant liquor is next to be let off, and the reſt of the proceſs continued exactly as in making the common fermented indigo.

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If the procefs has been properly conducted, the fupernatant liquor will run off, of a clear madeira wine colour, which will prove that it retains none of the indigo. To produce one pound of indigo, between two and three *hundred* pounds weight of green leaves will be neceffary, according to the feafon and ftate of the weather in which they are gathered: and at the end of Auguft or September, I have not obtained more than half or two-thirds of the quantity which had been yielded in May and June; and even that is leffened if the weather prove wet, or if the leaves are committed to the fcalding procefs immediately after being gathered.

This operation was performed with eafe twice a-day, and indeed it might be done three times; the fcalding in thefe large veffels requiring only about three hours, and the agitation and precipitation not more; fo that as foon as the fcalding of a fecond operation was completed, the fæcula of the firft was let out of the agitation-vat into the fmall fquare ciftern, where it was fuffered to remain till the fæcula had precipitated into a ftill fmaller bulk. The fupernatant liquor was then let off by the fcuppers, and the fæcula put into bags to drain.

Mr. de Coffigny, in his Treatife on the Cultivation and Manufacture of Indigo, obferves, that if the moift fæcula be wafhed with warm water, in which a fmall quantity of vitriolic acid has been mixed, it becomes improved thereby; which is alfo true of the nerium indigo. One ounce of this acid, for as much fæcula as will yield two or three pounds of indigo, I think fufficient ſufficient to diſſolve all the extraneous matters which are mixed with the fæcula, and they ought to be waſhed away by one, two, or more ſubſequent waſhings with pure water. I have found the marine acid anſwer nearly as well; but not the nitrous, which rendered the indigo porous. Theſe waſhings diminiſh the quantity of indigo remaining, but its beauty and value are greatly advanced thereby. Samples ſent to London, after being ſo treated, were valued at 25 per cent. more than the ſame indigo which had not undergone a ſimilar treatment. This, with the reduction of freight, ought, I think, to induce farther trials of this regenerating or brightening proceſs. When indigo is dried haſtily in the ſun, it is very apt to become friable or brittle, which diſadvantage may be in ſome degree avoided by ſlow drying in a ſhade.

From an account publiſhed in France in 1770, St. Domingo alone exported 2,000,000 of pounds of indigo, which paid the export duty; and the extent of country on the Coromandel coaſt, where the nerium grows, is greater than the whole of that iſland: and it undoubtedly grows in ſtill greater abundance on the Malabar coaſt, which is more mountainous, and of courſe more favourable to the growth of the plant: and I have lately been informed that Dr. Scott of Bombay, diſcovered it growing in the iſland of Salſet. The common indigo plant can only be brought to perfection in a good ſoil, and by expenſive laborious culture; and it is even then liable to many accidents from changes of weather, and other cauſes, which no human foreſight can prevent. I have not been able to find that this ſpecies of indigo is ſubject to any diſeaſe; nor have

have I ever once obſerved a leaf eaten by any inſect or other animal, except by goats and buf-faloes, who only eat it from neceſſity.

In the *ſecond* part of Dr. Roxburgh's communication, he gives a brief account of the reſults of various experiments made for the purpoſe of "throwing ſome additional light on the "theory of this artificial production (indigo);" and he profeſſes to have confined himſelf to ſuch experiments as cannot be well made in Europe; none of the indigo plants employed by him growing ſpontaneouſly there. It will be perceived, that Dr. Roxburgh, in deſcribing and reaſoning upon his experiments, adheres to the language and principles of that ſyſtem of chemiſtry which is now almoſt exploded by the later diſcoveries and doctrines of Lavoiſier, Cavendiſh, Berthollet, &c.; and in this reſpect I have not thought it proper to make any alteration; eſpecially as thoſe who are acquainted with the new ſyſtem will find no difficulty in underſtanding and explaining the ſeveral phenomena, according to it's principles and terms. It will alſo be perceived that I have generally adhered to the doctor's practice of deſcribing and reaſoning on his experiments in the firſt perſon ſingular; but it muſt not from thence be ſuppoſed that I have always copied his own words; for beſides the omiſſion of parts which appeared to me of leſs importance, I have frequently changed his modes of expreſſion for the ſake of perſpicuity and brevity.

"I have ſeen," ſays Dr. Roxburgh, "a ſhort "paper by Mr. Robert Blake of Calcutta, who "appears to think that the colouring principle of "indigo is held in ſolution by the aërial acid;

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"an opinion which accords with my experiments:" He (Mr. Blake) was induced to make some, which led to this conclufion by the opinion of Mr. Taylor of Manchefter, namely, that in the production of indigo, fixed air was abforbed from the atmofphere during the agitation. Mr. Taylor, in his Report to the Lords of the Committee of Privy Council for Trade, &c. obferves, that "the ufe of the violent agitation in the fecond "procefs has never been clearly afcertained in "any account he has feen refpecting indigo." "Its theory (fays he) certainly depends on the "great attraction which indigo in that ftate of "folution has for *fixed air*; by agitation and "expofure to the atmofphere, it abforbs it "from common air, and unites with it, and is "thereby precipitated. The fuccefs therefore "of this part of the bufinefs may be increafed "by fuch improvements in mechanics, as will "expofe the liquor with the largeft poffible fur-"face to the atmofphere, (that the affinity may "fooner take place,) and by procuring a great "circulation of common air in and about the "refervoir." So far Mr. Taylor agrees with me, that we both recommend the expofure of a large furface of the coloured liquor to the atmofphere, and a free circulation of air, which indeed is the main object in view.

When the common indigo plant is committed to cold water in the fteeping vat, the following appearances take place: in a few hours, more or lefs according to circumftances, a flight motion begins to fhew itfelf through the vat or body of liquor; the bulk increafes confiderably with fome additional heat; air bubbles are generated, fome ſome of which remain on the ſurface, and gradually collect into patches of froth; a thin violet, or copper coloured pellicle or cream makes its appearance between the patches of froth, and ſoon after, the thin film which forms the covering of the bubbles compoſing the froth, begins to be deeply tinged with a fine blue: The liquor from the beginning will have been acquiring a green colour, and now it will appear, when viewed falling from one veſſel into another, of a bright yellowiſh green, and will readily paſs the cloſeſt filter, until the action of the air makes it turbid, a proof that the (baſe of the) colour is now perfectly diſſolved in the watry menſtruum. This is the time for letting off the vat; if ſuffered to remain, the bulk begins to diminiſh, and will return to its original dimenſions; the fermentation however continues; there is ſtill much inteſtine motion through the vat; large quantities of froth are formed; hitherto the peculiar ſmell of the plant will have prevailed, but now it becomes very offenſive, ſomewhat reſembling animal matter beginning to putrefy; as the fermentation goes on, the ſmell becomes more and more offenſive, and the quantity of air diſcharged is leſs and leſs, till an abſorption takes place." When in the early part of the proceſs I held a glaſs tube to the mouth of a ſixty gallon caſk, which ſerved as a fermenting or ſteeping vat, that I might collect the airs, if any had been diſcharged, I found the wet bladder which had been tied over the upper end of the tube "ſtrongly preſſed in by the external air, a ſure proof that the vat in this ſtate abſorbed air; but as ſoon as the bulk of the maſs begins to be enlarged, a disengagement of airs takes place, and these are the fixed, pure, and impure: about the time when the bulk of the vat or liquor has attained its greatest increase, the fixed air is discharged in greater purity and in larger quantity than at any more early period; and it even continues to predominate until the 9th day, which I call the last stage. When the fermentation had advanced beyond the stage at which the vat ought to be drawn off, I found that a little agitation was necessary to promote a discharge of airs sufficient to fill a bladder." I could detect no volatile alkali in any part of the process: "During the agitating process, fixed air continues to be discharged, and in immense quantities, mixed with pure and impure airs; but still nothing like volatile alkali appears." As soon as the grain shews itself distinctly, the precipitant (alkaline or calcareous) is to be added; from that instant, an absorption of air takes place, and after the liquor has settled a little, a candle will burn freely close to its surface, as long as it would have done in the same quantity of atmospheric air; though, before, it had been constantly extinguished at the moment of its entering the mouth of the vessel. With nerium leaves the fermentation never became so perfect as with the common indigo plant; yet the airs discharged from it were the same, though less in quantity. "By scalding either the common indigo plant (*i. e.* young twigs and leaves) or the leaves (only) of nerium in bottles containing four gallons, nearly the same effects were produced, *viz.* first, an absorption of air, then an increase in the bulk of the mass, with a discharge of pure air at first,

 and

and afterwards of pure air mixed with fixed air, though in a proportion ſmaller than in the fermenting mixtures; here alſo during the agitation immenſe quantities of fixed air are diſcharged till the grain is formed and the precipitant added, when, as in the other caſe, an abſorption takes place. Here alſo a lighted candle burnt freely near the ſurface of the liquor, after the precipitant was added, and once I obſerved diſtinctly ſome exploſions of inflammable air. But the liquor being agitated, and a candle immediately after let down into the veſſel (bottle), it was inſtantly extinguiſhed upon entering its mouth."

I took ſome of the green coloured liquor, before it had ſuffered any agitation, and with it filled the globe of Dr. Nooth's apparatus for impregnating water with fixed air, into which (liquor) I continued throwing that fluid (fixed air) from a mixture of powdered lime-ſtone, and diluted vitriolic acid for ſome hours, but no change took place. After ſtanding till next morning, a very few grains of a greeniſh precipitate were found in the bottom of the veſſel, which I impute to the communication which the liquor had had with the open air before it was put into the globe; for when the leaves had been ſcalded in bottles of water, inverted in a large veſſel of water, or in the globe itſelf, and committed to the ſame trial, no grain was found; the liquor continuing uniformly of a pale yellowiſh green, which is the colour it always, in my experiments, acquired when ſcalded in the above manner. I kept ſome full bottles of it inverted in water for a month, and no change took place; nor does the liquor in theſe circum-

ſtances

ſtances ever acquire the copper-coloured film on the ſurface, but as ſoon as the air is admitted to it, greeniſh blue veins are obſerved to deſcend from the ſurface, in various directions, until the whole becomes blue. This phœnomenon is conſtant, but the colour is more or leſs deep according to circumſtances: ſoon after a precipitation of blue grains takes place, and the copper-coloured pellicle appears on the ſurface; but no change appears in the colour of the liquor, nor is any grain formed while the external air is perfectly excluded; neither do the leaves acquire that offenſive ſmell which they do when expoſed to the action of the air. "I may there-" fore, I think, ſafely conclude, *that fixed air is* " *not the agent by which this colouring matter is* " *ſeparated from its menſtruum, but rather that* " *by which it is extricated and kept in ſolution*."

Nitrous air from iron filings, and diluted nitrous acid, was alſo, by means of Dr. Nooth's apparatus, thrown into the coloured unagitated liquor for ſome hours, without producing any change, except that here the violet-coloured film took place; this liquor was afterwards expoſed to the open air, and the uſual changes then occurred.

Inflammable air from iron filings, and diluted vitriolic acid, deepened the colour of this liquor much, and it was quickly covered with a deep violet-coloured ſcum; but no decompoſition took place till the air had acceſs to the liquor, when it quickly became of a deep *greeniſh blue*, and let fall a conſiderable proportion of precipitate, which, on drying, proved to be moſt beautiful indigo. Inflammable air from dry ſheep's blood burnt in a gun barrel, as recommended by Dr. Prieſtley, had not the ſame effect as that from iron filings and vitriolic acid, the change of colour being much leſs conſiderable.

Alkaline air, from a heated mixture of three-fourths of quick lime and one-fourth of ſal ammoniac, deepened the colour of the liquor fully as much as the firſt mentioned ſort of inflammable air; it gave a deep violet ſcum and good indigo after expoſure to the open air, but nothing like a ſeparation took place before.

I put into bottles portions of the leaves of the nerium, and of the common indigo plant, to which I added rain water, impregnated with a large portion of what I have always found the moſt powerful precipitants, *viz.* lime water, cauſtic ley, ſtale urine, Pruſſian lixivium, and phlogiſticated calcareous lixivium, (of which more hereafter;) the bottles were inverted in a veſſel of water, and ſcalded to the uſual degree; the effect was, that they all became only of a much deeper colour than when no precipitant was uſed; but nothing like a ſeparation of the colour took place till expoſed to the action of the air. I alſo ſcalded the leaves in an open veſſel, and as expeditiouſly as poſſible, ſo as to allow the air but very little time to act on the liquor, and putting this into bottles with portions of the ſame precipitants, the bottles were immediately inverted in a veſſel of water; and having ſtood ſixteen hours, a little green or olive-coloured fæcula (precipitate) was found in each,

each, which I conclude muſt have ariſen from ſome little action which the air had on the liquor while ſcalding and pouring into the bottles. This precipitate, when ſeparated and expoſed to the air, became indigo of rather a bad quality; and the liquor from whence it had ſeparated, being afterwards expoſed to the air, became blue from the ſurface as uſual, and ſoon gave a blue precipitate of tolerably good indigo. Theſe experiments clearly prove, that the moſt powerful precipitants added to theſe liquors, cauſe no decompoſition without the help of the open air: and further, that if the air has had acceſs to this liquor, only while ſcalding, a very ſmall quantity of green or olive-coloured precipitate may be produced, but that this does not acquire a blue colour without the free contact of the air; they alſo prove that the colouring principle of Pruſſian blue does not act on this coloured liquor any farther than the alkali which it contains would have done by itſelf; it is therefore to be preſumed, that both the baſe and the colouring principle of indigo are totally different from thoſe of Pruſſian blue.

The coloured liquor, impregnated with the firſt principles of indigo, either by fermentation or by a ſcalding heat, if it be only expoſed to the open air, and eſpecially with a large ſurface, will in a ſhort time ſpontaneouſly begin to part with it colour, which will fall to the bottom in minute grains of fine blue indigo. Agitation will much haſten the ſeparation and precipitation, and cauſe the produce to be greater; heat will have nearly the ſame effect, though in leſs a degree, except when it is joined with agitation, in which caſe both agents will act more powerfully than either alone.

The indigo by all theſe means will prove good if the proceſs has been properly conducted; precipitants are not therefore abſolutely neceſſary to the production of indigo; but if well choſen, and in a due proportion, they will forward the operation much, and cauſe a larger precipitation than could be otherwiſe obtained without any injury to the quality, as I have reaſon to believe from a variety of experiments.

As far as my information goes, theſe precipitants are univerſally calcareous, alkaline, or aſtringent vegetable matters, of which lime-water is the moſt common, and I believe it is alſo the beſt, particularly with nerium; alkalis anſwer beſt when they are rendered cauſtic or deprived of fixed air; but even then the indigo obtained by lime-water will be found purer, though probably not in ſo great a quantity. It has already been obſerved, that fixed air forms a very conſiderable, I may ſay, the largeſt portion of the airs diſcharged during the fermentation, or ſcalding and agitation; and this being a fluid for which lime has the *greateſt attraction*, we may I think conceive the reaſon of its ſuperiority as a precipitant; for I am convinced that the colouring baſe of the indigo is held in ſolution by this acid, and that the more it is deprived of it before the precipitant is added, the more perfect will the granulation prove; and that a much ſmaller portion of lime-water (as a precipitant) will then anſwer perfectly well.

Next

Next to lime-water may be reckoned cauſtic ley, made from vegetable alkali and quicklime; this generally gives more of the precipitate, but its quality I have always found to be inferior to that by lime-water under ſimilar circumſtances. I have alſo obſerved, that this ley, when perfectly cauſtic, throws down ſome of the other extractive matters of the plant along with or before the blue. If the ley be added before the liquor has been agitated, or any granulation taken place, theſe extractive matters will generally be precipitated firſt in the form of a dirty pale yellow fæcula: and in the mean time, the ſupernatant liquor gradually acquiring from the ſurface a deep blue colour, will ſoon become turbid, and then a blue precipitate of real indigo will at length take place over the firſt; this proves the impropriety of uſing a cauſtic ley, where indigo of the beſt quality is deſired, as it ought to be by every manufacturer. This cauſtic ley changes the unagitated green liquor into one of a browniſh colour, which quickly becomes blue; and theſe changes proceed ſo ſuddenly as to eſcape notice without particular attention. When the ley is made leſs cauſtic, *i. e* by uſing a lixivium of wood-aſhes and lime-water mixed, it gives a better coloured precipitate, and perhaps one nearly as good as that of lime-water.

Stale urine is alſo a powerful agent: the colour of the indigo precipitated by it is always very bright, but conſiderably lighter than that with lime-water or cauſtic-ley.

When a green or olive ſupernatant liquor follows the uſe of lime-water or cauſtic-ley, (which is but too common in making indigo by fermentation, to the great loſs of the manufacturer,) I conceive it to be owing to the preſence of fixed air, ſtill adhering to, and keeping diſſolved a portion of the baſe; this fluid not having been ſufficiently extricated by the fermentation or ſcalding; or by the extent of ſurface, agitation and action of the agent employed *.

From this dark green or olive ſupernatant liquor, a farther precipitation may be obtained by the ſame means which produced the firſt, and it will be found when dried of as dark or darker a colour, but conſiderably duller.

In the northern parts of the coaſt of Coromandel, the natives uſe a cold infuſion of the bark of jambolifera pedunculata of Linnæus, (jambolong tree,) which is a very powerful aſtringent, to precipitate their indigo, which they always extract from the leaves by *hot* water; they have no idea that indigo can be made with cold; nor is it neceſſary to teach them on this point, what they make being of a very good quality. I have tried many other vegetable aſtringents, but without any good effect; the principles on which this one acts, I cannot determine.

* This opinion of Dr. Roxburgh's does not ſeem well founded; there is much more reaſon to conclude, that from ſome cauſe or other, the vegetable baſis of the indigo in this caſe, has not attracted and united to itſelf a ſufficient portion of oxygene, on which its blue colour moſt certainly depends.

The

The *mild* vegetable, mineral, and volatile alkalis act alſo as precipitants *, but leſs advantageouſly than thoſe already mentioned. Mineral acids added to the coloured liquor in ſmall proportions, either before or after the agitation, do not hinder the precipitation, though I cannot ſay they forward it †.

The ſolutions of iron, lead, tin, mercury, and copper, either injure or entirely deſtroy the colour ‡.

I have tried many other ſubſtances and mixtures, as well for the purpoſe of precipitating the colouring matter as of waſhing it when precipitated, but without finding any ſo uſeful as

* If it were true, as Dr. Roxburgh ſuppoſes, that the precipitants of indigo act only by abſorbing or ſeparating the fixed air, which he conceives to be ſtill remaining in the liquor united to the unprecipitated particles of indigo, it would be difficult to conceive how the mild alkalis, ſaturated as they are by fixed air or carbonic acid, ſhould occaſion any, even the ſmalleſt degree of, precipitation.

† One of the mineral acids poſſeſſes the power of diſſolving indigo without changing its colour; another totally deſtroys the colour; and the third appears to have no action whatever, either on the colour or the texture of this ſubſtance. If therefore ſuch very diſſimilar agents agree in not acting ſo as to hinder the precipitation of indigo, it muſt be only becauſe they are employed in proportions too ſmall to admit of their having any perceptible action; and in this way any thing may be rendered inactive.

‡ The facts ſtated in chapter fifth of this volume prove, that ſeveral of theſe metals act very powerfully, and in very oppoſite ways, either in promoting the ſolution of indigo, or in rendering it abſolutely inſoluble: it therefore ſeems inaccurate at leaſt to apply the ſame obſervation to ſubſtances of ſuch diſſimilar action, and capable of being ſtill farther varied by the various ſolvents here left undetermined.

lime for the firſt, and pure vitriolic and muriatic acids for the ſecond of theſe purpoſes.

Alum I have found to be a moſt powerful agent; but it debaſes the quality of the indigo. With the liquor of nerium leaves which had been ſcalded until they were beginning to boil, it produced a large quantity of green precipitate which retained its colour after being dried *.

Dr. Roxburgh concludes, that neither the nerium nor the common indigo plant yield any thing more than the baſe or baſis of colour, which he conceives to be naturally green, and to continue ſo, as long as it remains diſſolved in the aqueous menſtruum employed to extract it from the leaves; which, by being deprived of this baſis, become of a dirty yellow colour. He concludes alſo, that the fixed air, or carbonic acid gas, extricated ſo abundantly during the extraction of this baſis from the leaves, is yielded by them, and is the agent or medium by which the baſis is kept diſſolved; and that water, naturally impregnated with this acid and calcareous matter, is better fitted to extract a pure colour from nerium leaves, than it is when not ſo impregnated.

To precipitate indigo in the beſt form, and of the pureſt quality, (ſays Dr. Roxburgh,) means are to be uſed which weaken or deſtroy that at-

* Here by taking the baſis of indigo before it had become blue by an abſorption of oxygene, and uniting it as an adjective colour to alumine, it ſeems to have loſt its particular affinity for the baſis of pure air, and been diſpoſed to remain always green.

traction

traction which fixed air has for this vegetable base. These means are exposure to the open air, and agitation, together with quicklime and caustic alkalis (which have the greatest attraction for fixed air). By these, the vegetable base being disengaged from the fixed air, unites more perfectly with its colouring principle, which it greedily absorbs from the atmosphere, (assisted probably by the action of light,) forming therewith a coloured insoluble fæcula, which soon falls to the bottom. This precipitate washed and dried is then indigo. "I cannot "with any degree of certainty say, what this "colouring principle is, but I conjecture it is "that of *inflammability*."

I have already observed, that the Hindoos throughout the northern provinces or circars make all their indigo by means of hot water, (which I call the scalding or digesting process,) and precipitate with a cold infusion of the bark of the jambalong tree, which is a very powerful astringent: yet notwithstanding the inferiority of this their agent, (which habit has rendered sacred,) when its effects are compared with those of lime-water, I have always found their indigo, if it be not intentionally adulterated, to be of a very excellent quality, and *very light*; a cubic inch weighing only about 110 grains, and being of a blue violet colour. The superior quality of this indigo must alone be imputed to the nature of the process by which the colour, or rather base of the colour, is extracted from the plant; for their apparatus is very inconvenient. They use only common earthen pots, holding about four or five gallons each; in which the fresh

tops

tops and leaves of the common indigo plant are ſcalded, rather more than is neceſſary for extracting the colour from nerium leaves: they pay little attention to the nature of water, provided it be clear: their agitation-vat is nothing but a large jar; and the reſt of the proceſs is ſo careleſsly conducted, that the excellence of their indigo ſeems only to reſult from and be a proof of the ſuperiority of the ſcalding over the fermenting proceſs.

In many parts of the Carnatic, they alſo extract the colour by hot water, but debaſe the indigo by adding a mixture of red earth and water, which they employ as a precipitant.

Beſides the ſuperior *quality* of the indigo obtained by the ſcalding proceſs, the quantity is generally increaſed by it; for in this way the whole of the colour is always extracted at firſt, if the ſcalding has been continued long enough; which is not the caſe by fermentation, as the leaves will yield indigo upon being fermented a ſecond time. (See the Tranſlation of M. de Coſſigny's Treatiſe on Indigo.) Moreover the health of the labourer in this way is not endangered, as in the fermenting proceſs, by conſtant and copious exhalations of putrid miaſma: the heat employed expels moſt of the fixed air during the ſcalding, which renders a very ſmall degree of agitation, and very little of the precipitant neceſſary. The operation can alſo be performed two or three times a-day upon a large ſcale; and laſtly, the indigo itſelf dries quickly without acquiring any bad ſmell, or putrid unwholeſome tendency.

According

According to M. de Coffigny, the Javanefe firft ferment the indigo plant, then boil the coloured liquor a little before it is agitated, and do not feem to ufe any other agent to affift the granulation and precipitation. The indigo itfelf he defcribes as being very fine, and much efteemed in Europe, which I attribute to the boiling, or as I fhould imagine fcalding of the liquor.

To the fecond part, Dr. Roxburgh fubjoins an Appendix, containing a botanical defcription and drawing of a fecond *new* indigo plant; a fpecies of indigofera, which, fays he, I conceive to be a new one; and which on account of the property of its leaves, I have named indigofera cœrulea. It is called by the Hindoos of thefe parts car-necli; and is an erect fhrubby fpecies, growing naturally on dry, barren, uncultivated ground to the height of from one to three feet, and more in good garden foil. It nearly refembles the indigofera argentea Lin. the chief difference being that the new plant is wholly deftitute of down, and the leaves are never three'd, but always compofed of from three to five pairs of leaflets, with a large fingle terminal one, and the legumes are very numerous on the fame racemus.

From the leaves of the plant I have often extracted a moft beautiful light indigo, more fo than I ever could from the common indigo plant, or even from thofe of the nerium tinctorium, and in a large proportion. After an inquiry of two years, I have not been able to difcover, that the natives of any part of India

make

make any uſe of this plant. The proceſs, by which I obtained the colour from the leaves, was the ſame as that which had produced it from thoſe of the nerium, *i. e.* by committing them to cold water, and heating it over a moderate fire to about 160 degrees of Fahrenheit's thermometer, when the liquor will acquire a *beautiful deep greeniſh yellow colour*. It is then to be ſtrained off clear, and while hot, gently agitated in a broad, ſhallow, open veſſel for a few minutes, during which time it changes its colour, gradually becoming darker and more turbid; when ſufficiently agitated, if a little of it be viewed in a clean ſilver ſpoon, or other veſſel reflecting the light, a muddineſs or minute grain may be ſeen, which will be rendered large and copious by the addition of a little lime-water, and ſoon after precipitated to the bottom: after which, the ſuper-incumbent liquor being poured off, it will incline more or leſs to a clear brandy colour, according as the operation has been more or leſs ſucceſsfully conducted; for the more this liquor is tinged with green, the leſs perfectly will the colour have been ſeparated, and the produce will of courſe be leſs copious and beautiful. How to effect the moſt perfect ſeparation and precipitation of the colour, is the great *deſideratum* with our indigo manufacturers, and well deſerves the chymiſt's moſt ſerious attention.

On the 1ſt of September 1792, ſays Dr. Roxburgh, I ſcalded eight pounds of the leaves of the Indigofera cœrulea in hard water, and ſix pounds and a half in ſoft water; they required more ſcalding than thoſe of nerium, or even of the indigofera tinctoria, and more agitation to produce a granulation, particularly that with rain water, which has always, even with the other plants, seemed to act less effectually as a menstruum than hard water. The fæcula was precipitated by one part of lime-water to 75 of the coloured liquor, and being washed with diluted vitriolic acid, and afterwards with scalding water, when dry, afforded the most beautiful indigo I ever saw; that with hard water was the best, but the proportion of indigo was in both nearly the same, *i. e.* eight pounds of leaves with hard water, gave 241 grains; and six pounds and a half with rain water, gave 199 grains.

To the facts and explanations thus communicated by Roxburgh, I shall add but a few observations. His account of the appearances and changes which arise during the fermentation of the indigo plant, seems to be much more accurate than any yet offered to the public; many of them are however such as attend the fermentation of other vegetable matters, and not essentially connected with the production of indigo; as its generation or production by the *scalding* process, undeniably proves. For a knowledge of this process, we are indeed more especially indebted to Dr. Roxburgh; and the process itself seems highly interesting, because it doubtless must prove in many respects greatly preferable to the other; and because it presents to us a more simple view of the changes and effects which are essentially necessary to the production of indigo, divested of those which are common to other fermenting vegetables. The

appear-

appearances and succeſſive alterations through which the green liquor obtained by ſcalding the indigo plant, becomes finally blue upon the acceſs of air containing oxygene, and afterwards depoſits that ſingular fæculence under conſideration; joined to the abſolute impoſſibility of producing theſe effects, by any of the other airs and mixtures which Dr. Roxburgh very judiciouſly applied for that purpoſe, to the green liquor, *ſo long as it was kept ſecluded from oxygene, all ſerve to confirm* what I have advanced in the fifth chapter of this volume, and to prove that the blue colour, and the peculiar properties of indigo reſult wholly from a combination of oxygene with its vegetable baſis; and I am confident that Dr. Roxburgh, upon re-conſidering the ſubject, will accede to this concluſion.

I have no doubt of the poſſibility of obtaining the very beſt indigo from that which is of a very ordinary quality; the faults of indigo generally ariſe not ſo much from a want of the true colouring matter which belongs to it, as from an admixture of other heterogenous and uſeleſs matters by which it is debaſed; and from ſome trials which I have made, there is reaſon to believe, that theſe may all be diſſolved and ſeparated by powdering the indigo, and ſubjecting it firſt to the action of a lixivium of pot-aſh made cauſtic by lime, and afterwards, of the muriatic acid diluted by a ſufficient proportion of water; taking care firſt to rince and carry off by warm water whatever the alkali may have diſſolved: there is hardly any extraneous matter which one or other of theſe agents will not

not diſſolve, though neither has any action upon indigo itſelf. I prefer the muriatic to the ſulphuric acid for this purpoſe, becauſe it will prove at leaſt equally efficacious for diſſolving all, and more efficacious than the ſulphuric acid for diſſolving many of the heterogeneous matters in queſtion; particularly the oxyds of iron, and of other metals, without a poſſibility of its having any action upon the pure colouring matter of the indigo, which may not be true of the ſulphuric acid: for though the latter, when very much diluted, ſeems to have no power of diſſolving indigo; yet, I think, if it be uſed of a ſufficient degree of ſtrength to act efficaciouſly on the other adhering matters, there will be danger of its likewiſe carrying off ſome of the true colouring matter of the indigo, and thus occaſioning a diminution or loſs of that precious ſubſtance. It may however be doubted, whether any conſiderable benefit would reſult from this method of purifying indigo, (the ſaving of freight alone excepted,) ſince it could not add to the portion of colouring matter which the indigo previouſly poſſeſſed; and dyers now generally know how to eſtimate, and derive the utmoſt advantage from, that portion which even the worſt indigo contains. It is ſaid, indeed, that the ſulphuric acid brightens the colour of the indigo to which it has been applied in this way; an effect which I can readily believe, from its analogy to what happens from the application of it in making the preparation uſed for Saxon blue. This, however, muſt be a fallacious brightneſs, which can add nothing to the uſeful properties of indigo for any purpoſe, and may prove diſadvantageous for all thofe in which it is to be employed with an alkali; becaufe more of the latter will in that cafe be neceffary to overcome the excefs of oxygene, which the indigo will have acquired from the fulphuric acid, and which will have produced the fallacious brightnefs of its colour.

In the year 1793, one of the moft eminent mercantile houfes in London received from Bengal, parcels of two new drugs intended for dying; famples of which were foon after put into my hands, with a requeft that I would make fuitable trials of their merits; and with a paper containing fome explanations which had accompanied them from India. One of thefe (and the only one which I fhall notice at this time) was called by a name compofed of foreign words, fignifying *green* indigo. It was formed into dry hard cakes, refembling in fize and fhape thofe of the indigo fent from Bengal; but of a dark dull green colour. It was ftated to be a fimple fubftance, and to have been prepared with water and fire only, from an *indigoferous* plant, of which a defcription was indeed given; but I am in doubt, whether by publifhing it I fhould not go beyond the intentions of the author of this difcovery: it was alfo reprefented as giving a durable light green colour, without any mordant or bafis, to filk and wool; and to be incapable of dying dark green without the aid or addition of fome blue colouring matter. To bring this green indigo into a ftate fit for ufe, it was directed to be finely levigated with fand, and then boiling hot water was to be poured upon the powder in a fuitable veffel; and being left to fettle, the water "tinged with a dirty brown colour was to be poured off;" and theſe waſhings were to be repeated until the water came from the powder colourleſs; and then to the remaining powder, an equal quantity of fixed vegetable alkali, obtained by calcining ſalt-petre upon burning charcoal, was directed to be added, with a proportionate quantity of water, and the mixture made to boil for two or three hours; after which, it was to be left "to digeſt for two days at leaſt." In this preparation, diluted with boiling water, the ſilk or woollen ſtuff was directed to be dipped for the ſpace of half an hour, and then waſhed with ſoap in water; a longer dipping was repreſented as giving no greater body or depth of colour.

Thoſe who may recollect what I have mentioned reſpecting a ſuppoſed new green indigo, at page 144 of this volume, will naturally conclude, that my curioſity muſt have been greatly excited by that now under conſideration; and indeed I loſt not a ſingle minute in making a trial with it, which I knew capable of deciſively aſcertaining, whether it really poſſeſſed the properties of indigo, the difference of a green inſtead of a blue colour only excepted. This was by powdering and boiling it in water with a ſuitable portion of lime, pot-aſh, and red orpiment, as is practiſed in making the printers blue for penciling (ſee page 113, &c.); and in doing this, I ſoon perceived, with great ſatisfaction, that the mixture exhibited exactly the ſame ſmell, and the ſame appearances, as thoſe which ariſe in making the printers blue; the ſurface of the liquor was covered with a fine ſhining copper-coloured ſcum, and beneath this, when ſeparated, the liquor itſelf exhibited a lively green. Being impatient to ſee how far its effects were ſimilar to thoſe of indigo diſſolved in this way, I applied ſome of the green liquor as expeditiouſly as poſſible, by the pencil, to a bit of callico, and ſoon perceived that it conſiſted of two very diſſimilar colouring matters; one, which proved to be true indigo, was immediately revived by an abſorption of oxygene, (as happens to the printers blue when ſo applied,) whilſt another part of the liquor ſpread itſelf farther, and retained a kind of olive green colour, which the air did not change.

The callico after being dried was waſhed with ſoap, and that part of the liquor which had ſpread fartheſt, and retained the olive green colour, was ſoon wholly waſhed out, leaving behind the pure indigo adhering to the ſpots and ſtrokes where it had been applied. Having thus convinced myſelf that this ſubſtance contained a portion of true indigo, I powdered an ounce of it, and mixed the powder with ſix times its weight of ſulphuric acid, as in making the ſulphate of indigo for Saxon blue: in about twenty-four hours the powder appeared to be nearly all diſſolved, and the ſolution was of a blue colour with a greeniſh tinge: and by putting a little of it into warm water, and dying a ſmall piece of flannel therein, a full Saxon blue was ſoon produced; though the colour had a greeniſh caſt, occaſioned manifeſtly by the ſame olive-coloured matter which I have juſt mentioned as having ſhewed itſelf upon the callico.

I after-

I afterwards tried the method recommended by the author of this difcovery, of feparating the yellowifh brown colouring matter from the powdered green indigo, by repeated ablutions with hot water, and then employing a pure cauftic vegetable alkali to diffolve the refiduum. In this way I obtained a folution which, upon wool, dyed a light olive or apple green; I found however, as I had forefeen, that none of the true indigo had been diffolved either by my trials or thofe made in Bengal, it being impoffible, as I have formerly explained, to diffolve indigo by cauftic alkali alone; and indeed the difcoverer of this preparation, in the account which he tranfmitted from Bengal, candidly acknowledges that he had never been able to diffolve the fuppofed green indigo "entirely, a confiderable quantity having always remained precipitated at the bottom of the veffel." And this infoluble refiduum (which appears to have been loft, or at beft to have remained wholly ufelefs in all the experiments made in Bengal) I found by further trials to be true indigo. For by feparating the folution made by cauftic vegetable alkali from the refiduum, then pouring upon the latter farther portions of cauftic alkali in hot water, until the lixivium came away colourlefs; and afterwards fubmitting what remained to the action of muriatic acid, to diffolve any heterogeneous matters which the alkaline menftruum had left behind, I at length obtained a confiderable quantity of indigo of a middling quality; part of which, being diffolved by fulphuric acid, dyed wool of a good Saxon blue colour, without any of the greenifh tinge which had attended my firft trials; and another part being diffolved by

pot-afh,

pot-ash, lime, and red orpiment, as for the printers topical blue, produced the usual effects of indigo in this way. Having applied the acetite of alumine topically to a piece of cotton, as is practised in callico-printing, and dyed one part of it in the yellowish brown coloured liquor, which had been obtained by pouring hot water on the supposed green indigo in powder, and another part in the olive green liquor, obtained from the same powder by caustic vegetable alkali, I found that, though each imbibed a different colour, neither was fixed upon the figures which had been printed with the aluminous basis, or on the parts to which no mordant or basis had been applied, and that the colours were removed by washing with equal facility from every part: a certain proof that the yellowish brown and olive green colouring matters were not of the adjective kind, (having no affinity with the aluminous basis,) and that they are not likely to be of any use in dying; for though they should prove lasting upon woollens, there are many other and much cheaper means already in use, for giving colours of this kind to wool. It seems evident, therefore, that the true nature of the supposed green indigo was but very little known to the discoverer thereof; and that its useless heterogeneous parts were the only ones which produced the colours dyed in Bengal, and which induced him to send it to Europe as a dying drug.

Whether the supposed green indigo owes its production to an insufficient combination of oxygene; or, in other words, whether the matters which dyed the yellowish brown, and the olive

olive green colours, before mentioned, are ſimilar to that which forms the baſis of true indigo, and capable of being converted thereto by a longer fermentation, agitation, &c.; or whether they are of a nature eſſentially different from the baſis of indigo, though naturally combined with it in the particular plant from whence the ſubſtance under conſideration is extracted, are important queſtions which I am unable to anſwer. I have indeed mixed the ſuppoſed green indigo, in powder, with water, and kept the mixture for ſeveral days at a degree of warmth ſuited to promote a fermentation, but without being able in this way to render its colour blue, or increaſe the proportion of true indigo which it had before contained: but perhaps I might have been more ſucceſsful with a greater quantity, or a larger fermentible maſs, than what I was able to employ in this way.

I have had reaſon to conclude that the ſuppoſed green indigo, either from a redundance of colouring matters in the plant from which it was extracted, or from ſome other cauſe, may be obtained at much leſs expence than the true indigo; and if this be the caſe, it muſt doubtleſs prove a very important diſcovery, in caſe the yellowiſh brown and olive green matters are capable of being changed to indigo, by a farther combination of oxygene: and even if this ſhould not be the caſe, perhaps the plant may deſerve attention, on account of the portion of true indigo which it unqueſtionably affords; and which, by an alteration in the proceſs, might doubtleſs be precipitated and collected free from the other matters before mentioned, which, in

their

their preſent ſtate, muſt prove hurtful inſtead of being uſeful, as the author of this diſcovery had expected.

At page 145 I have ſaid, that no ſubſtantive vegetable yellow had, as I believed, ever been employed in Europe; I have however learned, ſince that part of the preſent volume was printed, that among other means for imitating the ſilk handkerchiefs brought from India and China, a tincture of turmeric is applied topically; and that it produces a *ſubſtantive* yellow, which on ſilk proves ſufficiently durable, and indeed much more ſo than I could have believed from the trials which I had before made with it in other ways. I have been ſhewn and have repeated the whole proceſs by which this imitation is very ingeniouſly performed; but it might be conſidered as a breach of confidence were I to publiſh any more on this ſubject.

END OF THE FIRST VOLUME.