MISCELLANEOUS

DISSERTATIONS

ON

RURAL SUBJECTS.

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THE

INTRODUCTION.

THE following Diſſertations are upon ſubjects of importance in rural oeconomy. Some of them have been treated of by others in a general way, but there is much room for improvement. This will appear on peruſal of the ſhorteſt of theſe, viz. that relating to Fences. The ſeveral methods of fencing in different counties are deſcribed, of lands of various kinds and different ſituations. The two principal uſes of fences are for ſhelter to lands, and to cattle that feed upon them; and as a ſecurity and defence from damages. The first of these is chiefly attended to, in making common quickset-fences. Much wood is planted, and this undoubtedly produces shelter; but much wood is no security against damage, and is itself an injury to the land. A moderate quantity of wood properly disposed, answers both purposes of shelter and defence, and cheap methods are here laid down to attain both; which it is presumed will be acceptable to husbandmen, who are sensible of the benefit of good fences, and of the damage and continual expence of reparing those that are insufficient. To render this article the more generally useful, the best practical methods are described, of securing lands from floods, and encroachments of rivers or other contiguous waters: for by these great injury is done, and much land washed away, which might be prevented, if the owners were acquainted with the means of doing it.

The next is a very extenſive article. Manures are uſed by huſbandmen univerſally. Without their aid, lands would ſink greatly below their preſent value. Farms that are much deficient in manure are low rented; but where manures abound, the tenant has the means of improvement, and can afford to pay a good rent. He may, notwithſtanding, uſe too much manure, or apply it improperly. Plants that are cultivated for their ſeed, as corn and pulſe of all ſorts, may be too highly manured: for a large quantity of manure promotes the growth of ſtraw more than the grain; and this may be carried to ſuch an exceſs, that the crops will be blighted, and no grain or very little produced. There is not the ſame danger in cultivating natural or artificial graſſes, not intended to ſtand for ſeed; yet even they may be over-done with manure, which will make them groſs, rot at bottom, and lodge.

The qualities of manures, and in what manner they operate upon land, are points of enquiry that merit the attention of all cultivators of land: in theſe we are not much aſſiſted by the common practice of farmers; who are not accurate in making experiments, and very rarely keep any regiſter of them. The operations of bodies, and of manures in particular, are traced with much difficulty; and what has rendered them the more ſo, is the propenſity to form hypotheſes upon thories, unſupported by experiments. It has long been a current opinion, that nitre or other ſalts were the cauſes of fertility; and conſequently, that thoſe manures that were

were found to be the greateſt enrichers of land, contained a large proportion of thoſe ſalts: this was ſaid of the ſeveral ſorts of marle, lime, and others. But when it was diſcovered by experiments, that they contained no ſalts, it was then ſaid that they attracted them from the air: but this alſo is now found to be an error; and therefore we muſt endeavour to account for the operation of manures, in ſuch manner as is warranted by accurate experiments.

This is not a matter of mere theory: juſt principles lead to a right practice, as we ſhall ſee in the preſent caſe. This rendered it neceſſary to enter into a diſcuſſion of the nature and operation of ſome of the principal manures; among theſe marle is to be ranked, the nature and operation whereof has been long imperfectly underſtood; and, though an excellent general manure, has to a proverb been excluded from ſtrong land. Marles differ in their qualities, but farmers had no other way to judge of them, or to diſtinguiſh them from other earths, but by their external appearances, in which ſome other earths, pernicious to land, very much reſemble them. To prevent the ill effects of ſuch a miſtake for the future, a method is here laid down to diſtinguiſh genuine marle with certainty, by a ſhort and eaſy proceſs, that the farmer may perform himſelf; and he is adviſed to do ſo, before he lays any earth ſuppoſed to be marle upon his land, whereof he knows not the effects from experience.

By this proceſs we may go a ſtep further, and not only diſtinguiſh marle from other earths of a like appearance,

pearance, but alſo diſcover the compoſition of the ſeveral ſorts of marle, and to what kind of land each of them is beſt adapted, for its improvement.

Chalk is much of the ſame nature as marle, particularly ſuch as is ſoft, ſoapy, and unctuous; yet chalk, till of late, has been eſteemed a manure proper only for ſtrong land, as marle was for light land. But chalk is now found to be a great improver of both ſorts, light as well as ſtrong.

The opinions concerning lime have been ſo various and contradictory, that many were deterred from uſing it: though the ill-conſequences that have enſued a plentiful liming, ſeem not to have ariſen from the lime, but from an injudicious management of the land afterwards, as may appear from this Diſſertation; wherein the reader will find ſeveral other points difcuffed relating to manures, tending to fettle a juft theory of their operation, and be of ufe to the practical hufbandman.

The Differtation on Drill-fowing relates principally to the new hufbandry; though that manner of fowing is not limited wholly to hoed crops. The drill-plough is an excellent invention. A great deal of feed is faved by it, and by the regular planting in rows, hoes of various forts are admitted to cleanfe the intermediate fpaces from weeds; and by ftirring the earth, both the crop and land is improved. Mr. Tull's drill-plough is a very good one, and anfwers in practice what he has faid of it. He conftructed it to fow double rows upon narrow ridges, for the purpofe of horfe-hoeing; and his land being moft of it light, and the drill drawn by a fmall horfe along the

the tops of the ridges, he made it very light; and is indeed too ſlight to be uſed upon very ſtrong land: but by a different conſtruction, here deſcribed, that inconveniency is removed. Another great improvement is alſo deſcribed here, which is new, and never before made public. Mr. Tull's drill-plough was conſtructed to ſow two and ſometimes three rows, but to ſow three the drill was too complicated. Some other drills have been invented ſince his, to ſow two, three, and ſome four rows; I had one made to ſow ſix rows at once, at the diſtance of ſix or ſeven inches. But in one particular all theſe inſtruments are defective; they ſow the rows at certain ſtated diſtances, from which they cannot be altered. But, after various attempts to remedy this inconvenience, I at laſt ſucceeded; by which Mr. Tull's drill will now ſow from

one

one to ſix rows, at ſuch diſtances exactly as the driller thinks proper. The contrivance to make it perform this, ſeems now ſo obvious, that it is ſurpriſing I did not diſcover it ſooner; and confirms the obſervation in mechanics, that thoſe of the ſimpleſt conſtruction are the beſt, and of the moſt difficult invention.

I ſhall not here enumerate the ſeveral machines that have been invented for drilling, ſince Mr. Tull's drill-plough: but there is one that deſerves particular notice, called the barrel-drill, which is an excellent inſtrument, firſt introduced by the celebrated Du Hamel. Imperfect indeed at firſt, but much improved by the ingenious Mr. Craik, and now made a perfect inſtrument. Upon Mr. Tull's conſtruction three drill-ploughs are neceſſary to ſow the different ſeeds uſed in the fields;

one for horſebeans and very large peaſe; another for wheat, barley, oats, common peaſe, and other ſeeds of nearly the ſize of theſe; and a third to ſow the ſmaller ſeeds, as thoſe of turneps, cole-ſeed, carrots, &c. But one barrel drill ſows all theſe; and a cheap method is deſcribed to make it deliver regularly the intended quantity of each per acre. Here is likewiſe ſhewn a method of conſtructing it, to ſow few or many rows, at the required diſtances. As now improved, it is a ſtrong and cheap inſtrument, eaſily managed; and of ſuch a plain ſtructure, that it may be made or repaired by workmen commonly employed in huſbandry buſineſs: ſo that upon the whole it is ſuch an inſtrument as the moſt ingenious cultivators have long wiſhed for, but has never before been offered to the public: and as it anſwers ſo well in every reſpect, there is no room to doubt,

doubt, but when generally known, it will come into more general uſe than any other of theſe inſtruments has hitherto done.

The next Diſſertation is upon Water-works, a ſubject of extenſive uſe. In very flat countries, as Holland, they have abundance of water; but that having no current, is of no uſe to them in their machinery, wherein they are obliged to make uſe of wind. Of windmills they have great numbers, and employ them in all manner of heavy work: for grinding corn, fulling, ſawing, in manufactures of paper, oil, metals, and many others; but with regard to power and ſteadineſs, water is far ſuperior to wind. In Britain there is great conveniency of water, but we are often defective in the application of it. Much more buſineſs might be done with the ſame

water,

water, if applied in the beſt manner. To aſſiſt thoſe who would erect ſuch works, and the workmen employed to erect or repair them, is the intentention of this Diſſertation.

The mechanic arts have their foundation in geometry. But in forming rules for practice, many circumſtances occur, that cannot be accounted for by theory alone, without experiments. Water raiſed to a head, and iſſuing through apertures made below, has in theory a certain velocity; and it has been ſuppoſed, as indeed it ſeemed probable, that the quantity iſſuing was conſtantly and directly proportional to the velocity; and upon that ſuppoſition, rules were laid down of the expence and impulſe of water paſſing through theſe apertures. But it appears from experiments that the quantity is not to be determined from the velocity,

and

and that the calculations of its impulſe, founded on that ſuppoſition, is erroneous: which is neceſſary to be attended to, in the conſtruction of all machines to be worked by the force of water.

The conſtruction of the bottom-work of mills, locks, ſluices, &c. with proper materials, and in ſuch manner as to prevent their decaying, and to ſecure them from blowing, are matters of no ſmall importance in theſe works: and concerning theſe, the reader will find here ſuch directions as may be relied on in practice.

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The manner of fencing low wet land.—Stone fences, different ways of making them.—The expence of making stone fences.—The best method of planting waste land with wood.—Estimate of the expence and profit of such plantations from experience.—Fencing with walls of chalk-stones.—The manner of building to make them durable.—Of fencing and improvements on the Yorkshire wolds.—Fencing with double stone walls and wood planted between them; the expence and advantage of fencing in that manner.—Of ditch and bank fencing with quicksets.—The plants most proper for quicksets.—The most approved methods of raising and planting quicksets.—And of training them to make strong and durable fences.—A new method of making cheap and secure fences.—Fencing with sets planted in single rows.—Of tree fences.—Furze fences, how to raise and manage them.—Of briar fences.—Bank fencing against rivers.—Several other methods of fencing against rivers.

Of FENCES.

THE first step to be taken in order to improve land to the greatest advantage, is to divide and fence it. Good fences are of themselves a considerable improvement. They are a shelter to the land and cattle; and secure the products of the land from damage both from cattle and from the inclemencies of the seasons. It is unnecessary to insist upon the advantages of inclosures and good fences; daily experience shews the general sense of their utility; and that open fields, upon being inclosed, immediately advance in value much beyond the expence of inclosing them.

There are various kinds of fences, which should be suited to the nature of the land to be inclofed, and the materials for that purpofe that the country affords.

For low, wet, or moift land, funk fences or ditches are the moft proper. In fuch moift, foft land, ditches are cut at a fmall expence, and anfwer a double purpofe, they ferve to divide the land, and to drain it. Ditches of fix feet wide at top, a foot and a half or two feet wide at bottom, and five feet deep, will make fecure fences, and prevent cattle from rambling. The foil dug out of the ditches fhould be laid on each fide; and a row of aquatic plants fet along one fide, within five or fix feet of the verge of the ditch, makes a good fhelter, and furnifhes a confiderable quantity of valuable wood. The proper fets for this purpofe are thofe of alder, willow, afp, abele, black and white poplar, and the white willow; moft of thefe rife to a great height, with naked ftems, and are moft fuitable to large fields; but for ſmaller fields they may be pollarded, or headed down to within ſeven or eight feet of the ground, which will make them grow with large thick heads, and afford a good ſhelter to ſuch fields. About nine or ten feet in length ſhould be left undug at proper diſtances (except a ſmall trench cut along the middle of each) for a communication to the water in the ditch. Theſe ſolid parts ſerve as bridges for carriages and cattle, and ſhould have a gate to each. The expence of dividing low ground in this manner is not much, and the improvement in the herbage, for feeding cattle, and hay, and the lop of the trees very valuable.

For waſtes, commons, and dry lands that lie high, that abound with ſtones lying on the ſurface, or beds of ſtone at no great depth, the beſt and cheapeſt fences are ſtone walls. The ingenious author of the Complete Engliſh Farmer objects, however, to these stone fences as follows:

"In Gloucestershire and Worcestershire, where larger tracts of waste lands are now enclosing, fencing is there carried on in two very different methods, neither of which, in my opinion, is the most effectual or least expensive; the first is, by digging stones, which in that part of the country every where abound, loading them in carts or wheel-barrows, and shooting them in lines, where they are afterwards erected into walls without cement, and extended for miles without any defence. This subjects them to many accidents, and it is no uncommon thing to see breaches in them of very considerable extent, by which means they cease to be a security, and are for ever wanting repairs."

Upon this it may be observed, that walls without cement, or dry stone walls, are to be seen in many parts of Britain, that

that have ſtood well time immemorial; but to inſure their duration the following precautions are neceſſary: 1. That they be not built too upright, but battering, ſo that they may be conſiderably narrower at top than at the foundation. 2. That the work be well bonded, by laying the long ſtones acroſs the walls at ſmall diſtances aſunder: this is abſolutely neceſſary, but in which the maſons are very apt to be negligent if not ſtrictly attended to, as every one muſt be ſenſible who has been concerned in ſuch buildings. 3. All ſuch walls ſhould be coped at top, without which they will be of no long duration. And, 4. gates ſhould be erected at proper diſtances, for huntſmen and travellers on foot to paſs, without damaging the walls. Theſe circumſtances being duly attended to, there is no doubt but ſuch ſtone walls will make excellent and durable fences; and it ſeems highly probable that a defect in ſome one or more of theſe particulars, was the cauſe of the walls above mentioned having ſuch breaches in them ſo ſoon after they were built.

The other method of fencing cenſured by the author is, " by making a kind of gutter on each ſide, and throwing the earth up in the middle, which riſes and forms a ridge about thirty inches high. About ſix inches above the baſe of this ridge they plant one row of quick, and about a foot above that they plant a ſecond row, and over all, the looſe earth from the gutters on each ſide, is thrown a-top, and thus their fence is completed. To defend the new planted quick, poſts and rails are ſet up on one ſide, and a ſort of clumſy ſlit gates are ſtaked upon the other. To this method of fencing the quick, I have no other objection except the expence of it; but againſt the manner of planting the quick much may be urged. Quick loves a rich, moiſt, loamy

ſoil,

ſoil, neither too wet nor too dry; and as its roots never deſcend deep in ſearch of nouriſhment, it feeds only on the rich paſture near the ſurface, and the richer and more enlarged that ſurface is, the better it thrives; but by cutting a gutter on each ſide they narrow its bounds, and by forming the earth on which it is planted into a ridge, they make way for that moiſture by which it is ſuſtained to drain off; ſo that though it may ſeem to thrive for a few years at firſt, it will certainly dwindle, and never arrive at its proper growth." In which opinion I cannot but concur with the author.

With regard to dry ſtone fences, Mr. Scroope, of Danby, near Richmond in Yorkſhire, incloſed nine hundred acres of moor land. The ſurface of the moor, ſays Mr. Young, yielded "in ſome places a ſufficiency of ſtones for this work; but in many others pits were ſunk for them; the

the quarries are all lime-ſtone, and moſtly near the ſurface. The firſt year two hundred and eighty-nine roods were built of the ring fence. This work was all contracted for by the meaſure, at 5s. 6d. per rood of ſeven yards long, and five feet high. A gate, two poſts, and the irons, came to 6s."

And ſpeaking of Mr. Danby's improvements of Swinton upon Moors, in the ſame county, he ſays, "The only method of Incloſure uſed here is that of ſtone walls, and moſt excellent fences they are. The ſtones ſcattered over the land they looſen from the earth with wedges, and ſplit them into ſmall pieces; theſe they lay upon each other very artfully, building with them the walls, which are not only very ſtrong, (laſting in full perfection beyond the memory of the oldeſt man) but have likewiſe a neat and good appearanee. A ſmall addition of the expence will cut them

them all into regular oblongs, which makes them look to the full as well as any the moſt regular brick walls.

"The expence of cutting (in the common manner), leading, and building the walls ſix feet high, is 5s. 6d. per rood of ſeven yards running meaſure. The gate-poſts are of ſtone, and excellent ones; their coſt ſcare any thing. A gate, irons, and poſts coſt 5s."

Sir Digby Legard has given a ſtill more particular account of theſe kind of fences on the wolds near Scarborough, and other matters relating thereto, which highly merit the attention of improvers of land in the like circumſtances.

"The eſtate, ſays this gentleman, where I have reſided ſeveral years, conſiſts of upwards of ſix thouſand acres; and the unincloſed part of it, or what is called wolds, of five thouſand acres, have never been let at more than a ſhilling per acre; and what I here ſay of a particular pariſh, is ap-

applicable to a very extenſive country, twenty miles long and fifteen broad. The ſoil of the wolds is in general a light hazle mould, in ſome places intermixed with ſmall ſtone, flint, or gravel. The depth of ſoil is from three inches to a foot, in general not leſs than five inches. Underneath there is a white lime-ſtone rock, by ſome called chalk, but I think improperly, it is more of the nature of marle. This ſtone riſes often in large blocks, and is uſed in building, and for lime. It is hard, but not of a very durable nature, for if it be expoſed to wet and froſt it ſoon cracks and moulders away; but if the walls built with it are kept well covered, it will laſt for ages. After a time it encruſts with a moſs, which preſerves it."

He then proceeds to ſtate the prices of labour, &c. in that country:

	l.	s.	d.
"The daily wages of a labourer in ſummer is 1s. in winter -	0	0	10
A carpenter per day - -	0	1	6
A maſon per day - - -	0	1	8
The day's work of a team, conſiſting of four oxen, two horſes, and one man and one boy - - - -	0	5	0
A ton of coals, including turnpikes, &c. coſts - -	1	4	0
A chaldron, or 32 buſhels of quick lime coſts - -	0	12	0
The ſame quantity burnt in one's own kiln, coſts - -	0	7	0
A lime-kiln built of brick, with two eyes, to hold 20 chaldrons - - -	15	0	0
Walling farm-houſes per rood, viz. ſeven yards, and one yard high - - -	0	4	0
A rood of wall, including getting up ſtones, lime, and building - - -	0	10	6

N. B.

	l.	s.	d.
N. B. Getting up is 5d. per load, leading as much; and four good loads will build a rood.			
Rough ſtone walls for fences, built without mortar, per rood - - -	0	4	0
Plaiſtering the inſide walls of farm-houſes per yard - -	0	0	2

Wood Fences. "As to wood for fuel and fencing, true it is that this country does not at preſent furniſh it; but it is no leſs true that it is capable of furniſhing enough for every œconomical purpoſe. The hedges and hedge-row trees round every village are a proof that the ſoil is not improper for wood; and ſome very thriving plantations on the tops of the hills, which a few gentlemen have had courage to raiſe, will be a laſting monument to their praiſe, as well as an example for others to imitate. Though the Scotch fir has been uſually ſelected for theſe trials, and has ſucceeded, yet the aſh will do as well, and is a much

much more valuable tree. For ploughs, fellies of wheels, and axles, for ſheep bars, and for the cooper's uſe, no tree is equal to it: it is beſides a very quick grower, and ſprings admirably from the old root. I confeſs that ſome plantations on the wolds have failed, but the failure has generally been occaſioned by an inſufficient fence, whereby the plants have been ruined by ſheep, their greateſt enemy, or they have not been planted thick enough at firſt: this is a common but a capital error. I find by experience that nothing is ſo eſſential to young plants as warmth; it is more material than depth or goodneſs of ſoil. Trees grow quicker and larger in good than in bad land, but ſome kinds will grow in any ſoil: without ſhelter no trees can exiſt. Remove ſome rich earth from a valley to the top of a mountain, plant a ſingle tree therein, and water it when neceſſary, no art will make it proſper. When trees are ſet very

cloſe

close together, so as at first almost to touch each other, they not only afford warmth, breaking the force of winds, but supply constant moisture to the roots. The rain and dew is not so soon exhaled, and the stagnation of air occasioned by the shade furnishes that putrid heat and fermentation so necessary for the purposes of vegetation. The mellowing and enriching the ground by a crop of turneps, and all the leguminous tribe which afford most shade, evince the truth of this observation. Raising wood in a bleak and exposed country is not only a desirable object, as affording a supply for fencing, fuel, implements of husbandry, and for buildings, but has this additional excellence, that if the plantations are discreetly placed, and the inclosures properly bordered with wood, all the adjacent land is considerably benefited, by being protected from the rage of impetuous storms; the grass grows better, and the cattle thrive

thrive much more on account of the ſhelter.

" Nor do I believe, that low-rented land, eſpecially the ſides of ſteep hills, can be turned to more advantage than by planting them. For inſtance, I have an incloſure of about ſix acres on the top of a high hill, which thirty years ſince was planted with Scotch fir, aſh, and beech. The trees are now at a medium twenty-five feet high; each plant will make four rails, and is worth 1s. 6d. they ſtand at about ſix feet diſtance from each other; therefore the ſix acres contain ſeven thouſand two hundred and ſixty trees, valued at 544l. 10s. the fencing this plantation and repairs coſt 30l. the plants, four years old, at 5s. per 100, coſt 18l. the rent of the land before the incloſure was 1s. per acre: deducting then 50l. for expences, the product of ſix acres in thirty years is 494l. But the compound intereſt on 50l. at 4 per cent. will, in thirty years, amount to above 60l. and there ſtill remains a clear profit of 430l.

" As there may be ſome difficulty at firſt, to procure poſts and rails for an extenſive encloſure; and as even a poſt, a double rail and a bank, is hardly ſufficient to turn a ſheep, I would recommend it to thoſe adventurers, who are about to incloſe, and can afford to lay out a little money extraordinary on an excellent fence, to have recourſe to the natural produce of the country, and make uſe of dry ſtone walls. I know that a ſtrong prejudice prevails againſt theſe materials; that it will be urged that the ſtone is periſhable; and that if this kind of fence was proper, it would long ago have come into general uſe, as the whole country abounds in ſtone. But let us not take opinions on truſt, or fancy with the vulgar, that any thing is impracticable, only becauſe it has not yet

yet been put in practice: the most obvious improvements have lain hid for ages.

"I have been making experiments for some years past, on the durability of the white stone, and have built several fence walls with it, in the most exposed situations, which have hitherto withstood the weather perfectly. The only precaution I used, was to dig up the stone early in the spring, that it might have the whole summer to dry (it is naturally very damp and moist), and so be better able to resist the frosts of winter; and to cover the walls with a projecting coping, either of whins or sods. This secures them from perpendicular rains: and though the sides are exposed to beating storms, the wind, which blows through, presently dries any moisture occasioned by the weather. Indeed, I find, that the more open the walls are built, the less liable they are to perish. That part next the earth is in most danger; and if it should be found neceſſary, the loweſt courſe may be laid with flint, with which the country abounds, and which is quite durable.

" Theſe fence walls are two feet thick at bottom and one at top; are four feet and a half high, excluſive of the coping; and ſeven yards in length coſts about 6s. But the price muſt in a great meaſure depend upon the diſtance of leading from the quarry, and on the eaſe of getting up the ſtones. In ſtating the above price I ſuppoſe that the ſtone quarry is not above five or ſix hundred yards from the work; and that a good labourer can get up at leaſt two loads in a day.

" A bank with a poſt and double rail with us coſts 3s. per rood, is hardly to be depended on, at firſt, as a fence againſt ſheep, and is perpetually out of repair. But though I ſtrongly recommend a trial of theſe ſtone fences, I would by no means exclude the planting of quick wood hedges; which afford the beſt

beſt ſhelter, and are highly ornamental. A double fence at ten or a dozen yards diſtance, and the intermediate ſpace planted thick with trees, hedges, and underwood, would be the moſt ſightly, the moſt convenient, and the moſt profitable."

"I have incloſed three hundred acres on the top of the wolds, and have laid down the greateſt part with various kinds of graſſes.—I generally give the land three or four ploughings, and ſow it in April or May, with graſs ſeeds, with or without corn. The latter way uſually ſucceeds beſt. I make my incloſures large, containing forty acres at leaſt; by which means the fencing is leſs expenſive. To incloſe forty acres with a double fence, at 6s. per rood, will coſt 150l. The preparation of the ground will coſt 42l. For the ploughing an acre four times, and the ſeeds requiſite, is worth a guinea. The intereſt of 190l. at 4 per cent. is 7l. 14s. but the annual advance by the inclosure I have found to be at least 8 s. per acre, consequently the advance on forty acres is 16 l. or above 8 per cent. interest, on the money laid out.

"But there are two things more to be taken into the account; one is, that where a large inclosure takes place, the side of one close is a fence for the adjoining one, which reduces the expence half. The other, that a border of wood makes the double fence necessary; and we have seen this amply repays the planter, at the end of thirty years. It is evident then, that the high wolds may, by inclosure, by the help of sheep fold, by cultivation, and a proper choice of grasses, be advanced 8s. per acre; and that the capital employed will pay an interest of 8 per cent. This has been done. The three hundred acres were as bad as any in the lordship; and the same improvement may extend to five thousand acres."

Sir Digby's double wall fences are expenſive; and, as he obſerves, are proper to be undertaken by thoſe only who can afford to lay out money upon ſpeculation and a proſpect of being reimburſed in a long courſe of years; where this is no objection, the plantations in the intermediate ſpace will very well repay the expence, even of the double walls. For the expence of building a rood, or ſeven yards in length of the double wall, is 12s. and the clear profit of the plantation, ſeven yards long and twelve broad in thirty years, amounts annually (in the proportion to his ſix acres) to 1l. 4s. 10d. an ample recompence for the money laid out.

Such plantations are very ornamental; and the excellent ſhelter they afford, when grown up, to the land and cattle, is a material conſideration, in ſituations ſo much expoſed to rough tempeſtuous weather.

But the moſt common fences are made with a bank and ditch, and the bank planted with two or more rows of quick-ſets, of white or black-thorn, crab, holly, maple, withy, buck-thorn, and ſeveral others; which are often, but very injudiciouſly, planted promiſcuouſly in the ſame hedge. The conſequence of which is, that the larger plants over-grow the others, and ſo ſtarve or ſtint them, that ſuch hedges are of very unequal growth, and have many gaps in them.

But the greateſt damage to ſuch fences is done by the trees commonly planted in them; for theſe, by their ſhade and drip, and robbing the quick of its nouriſhment, never ſuffer it to grow to a good fence. Add to this, that next the bodies of large trees the hedge is generally broke down, and the gaps want continual repairing with dead wood. Upon the whole, there are no good fences where large trees abound in them; and when planted

planted in the borders of ſmall encloſures, are extremely prejudicial to the crops. Where timber or lop-wood are wanting, other places ſhould be made choice of, to raiſe them; for large trees are inconſiſtent with good quickſet fences.

Quicksets

The plants moſt proper for quickſets are, the white or haw-thorn, the black-thorn, crab, and holly. The white-thorn is a pretty quick grower, when rightly planted in a proper ſoil. It is the moſt common, and makes a very good fence.

Black-thorn

The black-thorn alſo makes a good fence; not inferior to the white, if it likes the ſoil: but it is apt to ſpread its roots into the ground, and throw up many ſuckers, which makes it leſs eſteemed than the white; but the buſhes of the black are the beſt and moſt laſting for ſtopping the gaps in hedges; and it is not ſo liable as the white to be cropt by cattle.

Crabs

rab-tree. Crabs make a ſtout fence, if kept cut and trimmed to thicken it, otherwiſe they are apt to run up tall, with naked ſtems.

Holly. The holly is not ſo common as the others, becauſe it is a very ſlow grower, but when well managed, and not planted too thick, makes a good fence; and being an evergreen, affords a very good ſhelter in winter, when the others are deprived of leaves.

Furze. Furze is eaſily raiſed upon banks of poor ſoils, grows quick, and makes a good fence in a ſhort time.

White-thorn. The plants of the white-thorn are uſually gathered in woods or coppices; but the poor, crooked, half-ſtarved plants found there, are by no means to be depended upon, to make ſtrong good hedges; but ſhould be thriving plants, drawn out of a nurſery, and may eaſily be raiſed by the farmer for his own uſe. For this purpoſe the haws ſhould be gathered from young thriving trees, that ſtand

ſtand ſingle, and have the benefit of the ſun and air round them; the fruit upon theſe are uſually the ſoundeſt, and better ripened than thoſe that grow in hedges, where the plants are much crouded. They ſhould be gathered in November, when ripe, and in dry weather.

Haws. The haws will not grow the firſt year, though planted immediately, nor till the ſecond ſpring after they are gathered; and muſt therefore be preſerved till the proper time to plant them. This is done by digging a trench in a piece of dry ground, about eighteen inches deep, into which put the haws as ſoon as gathered; a thin layer of haws, and one of dry mould, alternately, to the depth of about a foot, and fill up the remaining ſix inches with mould; over which make a ridge of mould, and beat the ſides of the ridge cloſe with the back of the ſpade. This ridge will throw off the water, keep the haws dry, and ſecure them from froſt. Here

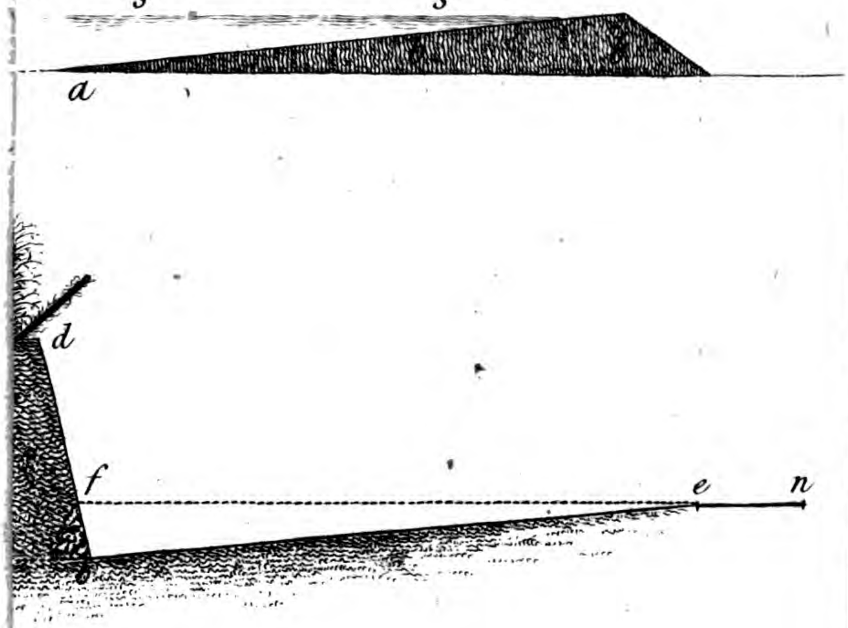
Here they are to remain near a year, viz. to the next October after they were gathered; and are then to be taken up and planted in the nursery, and in rows, for the conveniency of hoeing and weeding them. Some have directed them to be kept till the second spring after they were gathered, and then planted; but if delayed till then, many of them will have sprouted; and then if they are checked by rubbing off or wounding the sprouts, they will not grow. Other seeds that do not grow till the second year, may be preserved in the same manner, except such as are liable to be destroyed by vermin; for such should be put into earthen pans or jars, mixed with dry earth, the tops of the pans close covered with plain tiles or slates, buried in trenches, and the trenches covered with earth, in the same manner as the haws. They may likewise be preserved in boxes out of the ground; but the other way is the surest to preserve them sound.

Banks. Fences are often made with thin banks of unprepared earth, the face of the bank planted with two, ſometimes three rows of quickſets gathered in the woods, and another row on the top of the bank: theſe very rarely make good fences; being planted ſo thick, the plants are weak, and riſe in height with naked ſtems eſpecially if not kept clean from weeds when young. It is common to ſee hedges run up to a conſiderable height, but naked and open at bottom. Cattle eaſily make their way through ſuch hedges, and they are no ſecurity againſt hogs, nor againſt hares and rabbets. The goodneſs of quick fences does not ſo much conſiſt in their height, as in their thickneſs, and being well furniſhed with ſtrong branches near the ground.

The ſloping ſides of banks are improper to plant quickſets upon; for they throw off the rain water, and the plants are deprived of the moiſture neceſſary for their growth and nourifhment. Thick banks and rich moift earth is an exception to this: but fuch earth is not common, in many places where fuch fences are neceffary; and in every foil, the following method of planting is greatly preferable.

Firft mark out the foundation of the bank four feet broad, dig it a fpade deep or plough it. The ploughing or digging is to be continued from the foot of the bank twelve feet broad into the field on each fide. The digging is to be deepeft next the bank and gradually fhallower towards the field, as in Pl. I. fig. 1. where *a*, *c*, *d*, *b*, is a fection of the bank, and *b*, *f*, *e*, are fections of the ploughed ground on each fide of the bank; *a b* is the bottom of the bank four feet thick, *c d* is the top of the bank two feet thick, and *r s* is the perpendicular height of it four feet. The ground on each fide of the bank, is to be of fuch breadth, that the

2.



J Lodge sculp.

the earth dug up there may ſerve to make up the bank to the intended height and thickneſs. As in the preſent caſe the area *s*, of the two ſections of dug or ploughed earth *a*, *f*, *e*, and *b*, *f*, *e*, amount to twelve ſquare feet, and the area of the ſection of the bank *a*, *c*, *d*, *b*, is alſo twelve feet, and therefore the earth dug up is juſt ſufficient to make up the bank.

The foundation of the bank is made with turf laid length-ways, and joining to the lines made to mark out the foundation, and the intermediate ſpace filled with earth, beat down cloſe and level with the turfs. The next layer ſhould be of turf, laid acroſs the firſt, and of ſuch a a length that their ends may meet in the middle within a foot; and at every ſix or ſeven feet diſtance, the turfs laid acroſs ſhould be long enough to reach the whole breadth of the bank, and theſe ſerve to bind the whole together. The intermediate ſpace in the middle being filled up and beat level with the turf and earth as the firſt, make then two more layers as before, and proceed in the ſame manner, until the bank is raiſed to the intended height. * As the work is carrying up, the outſides of the bank ſhould be beat cloſe and ſmooth, and this repeated afterwards when they are moiſt with rain, which will cloſe the ſeams, and unite the whole into one ſolid body. The middle of the bank ſhould be filled with good mould, eſpecially towards the top, where the fibrous roots of the ſetts will be moſt numerous. The top of the bank ſhould be two feet broad, filled with the beſt mould, and levelled.

The beſt time to raiſe theſe banks is early in the ſpring; the graſs will form a ſwarth on the ſides of the bank in ſummer, which being beat cloſe and ſmooth when they are moiſt, will effectually conſolidate them: and ſuch banks well made

at

firſt, will laſt many years, and want very little or no repairing.

Transplanting Quicksets. It is cuſtomary to tranſplant quickſets in the ſpring; but if dry weather ſucceeds, many of them are killed, or ſo much weakened that they never recover: nor are ſlight ſhowers of rain ſufficient to keep them moiſt, becauſe they are planted upon ſloping banks. The beſt time to tranſplant theſe ſets is in October; for though they do not grow in winter, they are preparing to throw out new roots and buds early in the ſpring, and proceed in their growth without any check, which thoſe tranſplanted in ſpring are always liable to.

Fences made in this manner, are in every reſpect preferable to thoſe commonly made with ſloping banks; with this further advantage, that theſe do not require ditches to carry off the rain water. The ground on both ſides being dug ſhelving towards the foot of the bank, ſerves to carry off the water; and as the ground is dry again in a ſhort time, cattle may lie cloſe to the bank, which makes a very good ſhelter for them. Nor is any ground loſt; the ſloping ſides being ſown with white Dutch clover ſeed, is a paſture for the cattle; and ſo is the ſides of the bank, that produce ſome graſs, to which the cattle can reach to feed upon them. The dimenſions of the banks here laid down, are ſufficient for any common inſide fences. But for outſide fences or much expoſed places, the banks may be ſomewhat thicker and higher and the quickſets having more mould to ſpread their roots in, will grow the more vigorouſly.—When theſe fences are made in declining grounds, that lie ſhelving towards one ſide of the bank, the rain water that runs from the field, together with what runs that way from the ſlope dug up to make the bank, may accumulate to ſuch a body of water, as may wear

away

away the foot of the bank. In ſuch ſituation the foot of the bank may be defended by ſtones laid under the foundation, as at *f*, *b*, Pl. I. fig. 1. Or if that is not ſufficient make a ſmall ditch near *b*.

As the bank ſhould be made in the ſpring, and the ſets not tranſplanted until autumn, the mould at the top of the bank ſhould in the mean time be repeatedly well dug or hoed, which will be a ſummer fallowing to it, will keep the earth mellow and open, and cleanſe it from weeds more effectually than can be done after the quick is planted.

Trimming the Plants. The ſetts ſhould not be tranſplanted from the nurſery until they are at leaſt half an inch thick: their tap-roots when taken up, ſhould be ſhortened to ſeven or eight inches, the fibres trimmed, and the tops of the ſets cut off to within two inches of the crown of their roots, and immediately tranſplanted upon the banks in a double row, each row ſix inches diſtant from the verge of the bank, which will leave a ſpace of a foot wide in the middle between the rows; the plants at four inches diſtance in the rows. They ſhould be planted when the earth is moiſt or an appearance of rain, with a trowel, which is a much better way than with a dibble.

Next ſummer the ground ſhould be kept clean from weeds, and if hoed between the rows the plants will thrive the better. In October cut down the ſhoots produced in ſummer to within ſix inches of the ground, and cut the ſide branches within two inches of the ſtems. This cutting will thicken the ſets at bottom and no more cutting will be neceſſary, but to trim up the ſides every autumn with a ſharp hook. The ſtrong leading ſhoots that overtop the reſt ſhould alſo be ſhortened, and the hedge cut at top when riſen to about three feet and a half high; for then the bank and hedge together will

will be between ſeven and eight feet high,* which will be a defence againſt any cattle, or deer..

To prevent cattle from cropping the young quickſets, ſtakes of two feet and a half long ſhould be driven near a foot deep into the top of the bank, next the edges on each ſide, and leaning outwards. Into theſe ſtakes work in buſhes of the black or white-thorn, or ſtrong furze, with the bruſh outwards; which will ſecure the quick until it is grown up and out of danger. By this method an immediate fence is made, and when the quick is grown up, is much ſuperior to the common fences, and advances to maturity in a ſhorter time.

Manner of raising Quicksetts

The uſual method of raiſing quick hedges is from ſets; yet it is ſtill a better way to raiſe them from the ſeed, which may be very conveniently done upon theſe banks. As, inſtead of taking the ſetts from a nurſery, the haws are ſown directly from the trenches in which they were laid the first winter, into the ground where they are to remain. Sow them in two drills on the top of the bank, in October, at the same distance as the sets; but much thicker in the drills, or not above an inch apart. They will come up the same as in the nursery, and are to be kept clean in the same manner by hoeing and weeding. When they are come up, it may be seen in summer which are the most thriving and strongest plants; these are to remain, and the weak ones are to be drawn up carefully in October, leaving the others at about four inches distance in the rows. The remaining strong plants may afterwards be managed as directed for the setts. In this method there is no time lost, but, on the contrary, the plants from seed, having long tap-roots, and a greater depth of mould to grow in than those in the nursery, and not being checked by transf-

plant-

plantation, will make a quicker progreſs, and become ſtronger plants than they. For it is found by experience, that plants raiſed from ſeed, will outgrow the tranſplanted ſetts, when both are equally cultivated in every other reſpect, and in the ſame ground. It has indeed been ſaid, that tranſplanted lucern grows more vigorouſly than the ſeedling plants, when both are cultivated alike, and in the ſame ſoil; but it is to be obſerved, that in the experiments made upon this plant, the tranſplanted lucern was always allowed moſt room: for though the rows of both were at the ſame diſtance, yet the plants were not ſo in the rows; the tranſplanted being ſet at ſix inches diſtance, or more, in the rows, but the others were ſown thick in them by hand: ſo that in this reſpect, there was no juſt compariſon. As two rows of quick-ſetts make better fences than three or four, it may be worthwhile to enquire, whether a ſingle row may not do as well, or better than a double one. By ſome experiments made with ſeveral quickſets, particularly with crabs, I have ſome ground to think that very good fences may be made with a ſingle row. It is obſervable in old hedges, where the plants of black or white-thorn have been cut down, there ariſes from the ſtumps, ſuch a number of ſhoots, ſo ſtrong and full of long ſharp ſpines, that no cattle will attempt to get through them; being much ſtouter than the common ſhoots in the ſame hedge. This is occaſioned from the numerous roots of ſuch plants, which furniſh the young ſhoots with a larger proportion of nouriſhment: and the ſame is obſerved in fruit trees when much pruned, they grow more luxuriant, and produce more wood, than they did before. By the amputation of their branches, their roots bear a larger proportion to their heads, and furniſh them with

with a larger ſupply of the vegetable aliment. Upon this proportion depends the thriving of plants in general: and as the growth and vigour of the roots of a ſingle row, can be more encouraged and promoted by cultivation, than thoſe of many rows crowded together; the vigour of the ſingle plants will be in proportion.

The goodneſs of ſuch ſingle fences does not conſiſt ſo much in their lateral branches, as in the ſtems of the plants: for when they ſtand pretty cloſe in a line, they form a ſtrong fence. Thus the ſtem of a plant of the white or black-thorn in a thick hedge, is eight or nine years in gaining an inch in diameter; which may be ſeen by cutting their ſtems acroſs, and obſerving the number of rings or circles, in them: each circle is a year's growth. But ſtanding ſingle, and well nouriſhed, will gain as much in little more than half that time; and there-

therefore in a ſingle row, ſet at the diſtance of ſix inches, the ſtems will approach ſo near to each other in a few years, that no cattle can paſs between them; eſpecially if ſtrengthened and held together, by working ſome rods in between them.

Crab-plants But the ſtrongeſt fences of all, and impregnable, may be made with plants of larger growth than the thorns or crabs, planted near each other in a ſingle line, upon ſuch a bank as is above deſcribed. All trees that riſe with ſtraight ſtems are fit for this purpoſe, the elm particularly, the beech, and hornbeam. Elms are remarkable for growing well in conſort; and may be frequently ſeen growing in hedges thirty or forty feet high, and ſo cloſe that their trunks almoſt touch one another. No cattle are able to penetrate a line of theſe trees ſo planted.

It is not, however, neceſſary that they ſhould riſe to ſuch a height for a fence.

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But if topped at the height of ten or fifteen feet, and the branches kept cut on the two oppoſite ſides, they make one of the moſt ſecure and durable fences imaginable, and afford an excellent ſhelter, without injury to the products of the fields ſurrounded by them.

Horn-beam. The horn-beam may be raiſed from ſetts, or ſeeds, and trained in the ſame manner, and has one advantage above the others, that it uſually retains its leaves in winter, and makes a warm ſhelter then to graſs and cattle.

Furze. Furze makes a good fence in poor land, where few other plants will thrive. The uſual way of raiſing it, is on the tops of the banks, from ſeed ſown in autumn, or early in the ſpring, in one or two rows. But in this way it riſes too thick, and the plants ſo crowded, that they are much weakened; and as they root ſhallow, are very ſubject to die in patches, and the hedge is of little ſervice. The beſt way

way of raising them is on the top of ſuch a bank as above deſcribed; the ſeed ſown very thin, in two rows, as common quickſets, the rows at a foot diſtance in the middle of the banks, and ſix inches from the verges on each ſide. When they are about half grown, cut down in October one of the rows almoſt cloſe to the ground, which will ſoon ſpring up again; and as ſoon as this has advanced about half way, cut down the other row in like manner. By proceeding thus to cut the rows alternately, the bank will never be left quite bare; and by cutting them down before they are grown old, they readily produce new ſhoots. The neglect of this is the principal cauſe that furze hedges are ſo apt to die when cut. The furz moſt proper for theſe hedges, is the ſort called French furze, being of a larger growth than the common ſort.

There is, however, one inconveniency that commonly attends furze hedges; they

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are apt to produce confiderable quantities of feed, which being blown about by the wind, or carried thither by birds, fill the contiguous lands with young furze; and this being repeated every year, it is troublefome and expenfive to keep the land clear of them. This may in a great meafure be prevented, by trimming the fide branches with a hook, which will make them grow thick and clofe, and obftruct their bloffoming: and many of the branches that would produce feed are cut away. For thefe reafons the round furze bufhes upon commons produce none. They are continually cropt by cattle and fheep, and grow fo thick and clofe, that the fun and air have not free accefs to encourage their bloffoming and production of feed.

There are fome foils fo poor, that they cannot be fenced with quickfets: for fcarce any plants fit for that purpofe will thrive in them. There is a remarkable inſtance of this in a letter to the Edinburgh Society; the author whereof ſays he had been twenty years a farmer in England, and when the letter was wrote he lived and occupied land in Scotland, which he attempted to incloſe with quickſet hedges, but without ſucceſs. The land was ſo light and ſandy that he could not make banks ſufficient, and his cattle eat or trod down every kind of fences he attempted to raiſe.

At laſt obſerving, that none of the cattle touched the briar or eglantine plant, that grew naturally upon his land, he determined to try it for a fence; and for that purpoſe gathered a quantity of the hips in Autumn, kept them in ſand during the winter, and in ſpring rubbed out the ſeed and ſowed them in drills upon his low banks; they ſhot up to ſuch a conſiderable height, that the ſecond ſummer they made a good fence, few of his cattle venturing to break through it.

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Sometimes, he ſays, his ſheep attempted it, but were ſo entangled in the prickly buſhes that they could not extricate themſelves, and would have died there if he had not cut them out. The letter was wrote ſome years after he had raiſed theſe fences, which, he ſays, continued ſtill to thrive and grow vigorouſly; and thus he obtained good fences at a very cheap rate.

Another plant, that, if rightly managed, would make make good fences, is the bramble. In good moiſt land it makes long vigorous ſhoots in a ſeaſon, and upon banks where it gets footing, it over-runs moſt other plants, grows ſo thick, and entangled together, that no cattle, or even hogs, are able to make their way through it. It will grow from ſeed or layers, and if raiſed on the top of a good bank, this deſpiſed plant would without doubt make a ſtrong fence in a ſhort time. It naturally trails upon the ground;

ground; but if worked into ſtakes driven into the bank, a ſtrong eſpalier fence might be made with it, a yard or more in height. As lands of different ſorts and ſituations, require different methods of fencing, and in others a variety of them, I have been the more particular, that every perſon may make choice of ſuch as he thinks will be moſt proper for his ſituation: without good fences no farmer can make the moſt advantage of his land; but will be liable to continual expence to keep his fences in repair, and to receive much damage in his crops from the neighbouring cattle, and his own; and therefore he will find his account in making his fences ſtrong and ſubſtantial at firſt, and never ſuffer them to run to decay, for want of neceſſary reparation.

Lands that lie contiguous to rivers, and large pieces of water, and are ſubject to be overflowed by them, require to be fenced

fenced in a manner different from any hitherto mentioned, by banks of earth, of a height and thicknefs, proportioned to the rife and motion of the water.

Still water does not much wear the banks, as of ponds and other ftagnated water, where the banks, though fteep, laft a confiderable time without much repairing, efpecially fuch as confift of ftrong tenaceous earth. But the banks of rivers that have a quick current, of tide rivers, and wherever the water has any confiderable motion, are there continually wore down and wafhed away by the agitation of the water.

The current of rivers is ufually quickeft at the furface, and for that reafon the banks would be firft worn away at or near their tops; and this happens where they have no covering to defend them; but in meadows where the banks are covered with grafs, the roots of the grafs are interwoven and matted fo clofely, that they bind and hold together the top mould, which the current cannot ſo eaſily looſen as the lower part of the bank, that lies expoſed to the water, and has no roots of graſs to ſecure it. Hence it is that ſuch banks are worn away hollow below the turf, till the upper part, thus deprived of its ſupport, becomes top-heavy, breaks off from the land, and falls into the river.

In this manner the ſteep banks of rivers are waſhed down; as thoſe of the Severn, where ſometimes a great part of an acre of the land, breaks down at once, and is waſhed away. This always happens at an elbow or bending of the river, which is continually gaining there upon the land and retiring from the oppoſite ſide.

The banks made againſt a river, to ſecure the contiguous lands from being overflowed by it, ſhould be raiſed higher by a foot and a half, than the river is ever known to riſe to, in the greateſt floods, after allowing for the ſettling of the

the earth whereof the banks are made, which is greateſt in ſoft loamy ſoils. Theſe banks ſhould by no means be made like a wall, with a perpendicular or upright ſide facing the river; for ſuch upright banks, are, for the reaſons already mentioned, no durable ſecurity againſt running water. But the banks ſhould be made ſloping from the higheſt part down towards the river; and the more gently they ſlope, the leſs liable they are to be worn away by the ſtream, or motion of the water.

Pl. I. fig. 2. is the ſection of a bank made againſt the river *r r*, gradually higher from *a* to *b b*, where it is raiſed above the higheſt flood *s s*, and being made of good earth, and covered with turf, well beat down to cloſe the ſeams, will perfectly ſecure the adjoining lands from being overflowed; and if well performed, will laſt for a long time. No general rule can be laid down for the exact ſlope of theſe banks, nor is a ſmall variation of conſe-quence, provided the earth they are made of, and the turf with which they are co-vered, are of good earth.

But where the banks are conſiderably higher than the common ſurface of the water, though theſe banks will prevent the floods from extending further upon the land, they cannot ſtop the waſhing and wearing away the earth of the up-right banks next the river, but they will, without ſome further ſecurity, be con-tinually ſubject to waſh down, become hollow, and wear away. To defend them with wharfing of ſtone or timber only, for the purpoſe of ſaving ſome land, would be attended with an expence that the value of the land ſaved is not ſufficient to repay; unleſs where ſuch wharfing is neceſſary to ſecure houſes, or other buildings; or to make a con-venient key for loading or landing of goods.

The

The cheapeſt method for this purpoſe, is by ſuch fences as the Dutch make, to ſecure their dams from the ſea. They are made in the water, near and parallel to the banks; and though not ſtrong enough of themſelves to defend the banks, yet being ſupported on both ſides by the water, the force of its motion is ſo much weakened, by the reſiſtance of the water on the inſide of the fences, that it is very gentle there; and the banks are then wore but little more than the banks of a pond, or other ſtanding water.

Theſe inſide fences are made by driving a row of ſtakes or piles in the river, parallel to the bank, and near together, to ſtand as high as the ſurface of the water, and into theſe ſtakes are to be worked buſhes of black or white-thorn, or furze, which are very proper for this uſe, with the bruſh pointing towards the river. This hedge being ſupported by the water between it and the bank, reſiſts and ſtagnates the current or tide in the river, and is by that means a great ſecurity to the bank.

Another method that ſome take to ſecure banks from the waſhing of the water, is by ſmall wings or jettees of timber projecting from the bank a little way into the river. Theſe check the current of the water from one wing to the other, and anſwer the end very well while they laſt; but the check given to the ſtream cauſes an eddy between the wings, and as the water riſes a little there, and, by its weight and motion, wears away the earth at the ſides and bottom of the wings, the timber work is thereby looſened, and then carried away by the current.

When there is plenty of ſtones or large chalk at hand, and the owner is willing to be at the expence of it, ſuch banks may be effectually ſecured by throwing in the ſtones or chalk cloſe to the bank, and laid

laid ſhelving from the ſurface of the water next the bank to ſome diſtance into the river. The longer the ſlope is made, the more ſecure it will be, and the leſs liable to be carried away by the ſtream. And in order to ſecure it from being carried away or removed, rows of piles ſhould firſt be drove into the bed of the river, acroſs the ſtone-work, the heads of them to ſtand as high as the ſurface of the water next the bank, and gradually lower, the further they extend into the river, ſo as to anſwer the ſlope of the ſtones or chalk, above which it is not neceſſary they ſhould riſe.

The ſlope, or ſhelving of the ſurface of this work, may be determined by extending it into the river to twice the diſtance of the depth of water. Thus ſuppoſe the water is ſix feet deep at the bank, the ſtone work ſhould extend from thence twelve feet into the river, ſloping all the way. If it is carried out further it will lie the more ſecure, but ſhould not be of a leſs extent, unleſs the ſtones are very large.

The piles ſhould be driven before any ſtones are thrown in, in rows three or four yards diſtant, and at ſuch diſtance in the rows that the large ſtones cannot paſs between them. Piles of oak are ſtrongeſt, but fir piles are alſo very proper; for if they are of ſound timber at firſt, they will never decay, as they are conſtantly under water: nor can they be wore away by the ſtream, being on all ſides defended from it by the ſtones. Large ſtones ſhould be thrown in at top, and ſmaller between; and the gravel and ſand brought down by the current will fill up the cavities, ſo that the whole will in a ſhort time become a cloſe ſolid body, and effectually guard the bank from any wearing by the motion or current of the water. In this manner I ſecured the bank of a rapid river, about nine feet deep, above twelve years ago, and the work

lies

lies firm, notwithſtanding the rapidity of the ſtream that continually waſhes it, and frequent high floods to which the river is ſubject.

Admitting the depth of the water to be ten feet, and the work to extend twenty feet into the river, theſe two lines being two ſides of a triangle, right angled at the bottom of the bank, will determine the quantity of ſtone work, the ſection of which, in this caſe, will be a hundred ſquare feet in the area, and every foot forward will require one hundred cubical feet of ſtone work, or about three cart loads; and thus the expence is eaſily computed, according to the diſtance from which the ſtone is to be brought.

MISCELLANEOUS

DISSERTATIONS

ON

RURAL SUBJECTS.

The ſeveral kinds of manures uſed in huſbandry.—Of the operation of manures upon land; and the different things relative thereto conſidered.—Of the principal ſingle manures, marle, chalk, lime, and limeſtone-gravel.—A ready method of diſtinguiſhing marle from other kinds of earth.—Of the compoſition of marles, and what ſoils each ſort is moſt proper for.—A pernicious ſort of clay reſembling marle, and how to diſtinguiſh it.—That marle does not attract ſalts from the air.—The methods of ſearching for marles, and other foſſil manures.—Chalk beneficial to both ſtrong and light lands. The manner of its operating on both.—Lime by ſome ſuppoſed to be an impoveriſher of land. The ground and error of that opinion.—Several ways of burning ſtone and chalk into lime.—The beſt conſtruction of a lime-kiln.—Of ſoap-boiler's aſhes; the different ſorts of them.—Of ſheep's dung, and folding.—Of compoſts, and the beſt way of mixing them.—Of powdered manures; and foul ſalt.—Of new compoſts, recommended by Dr. Hunter of York.—Of liquid manures.

Of MANURES.

THE ufe of manures is to enrich land, or to correct its too great ftiffnefs, loofenefs, or other natural imperfections.

Many different fubftances are made ufe of for thefe purpofes; and it is found by experience, that moft kinds of matter, which ferment, corrupt, or fall into powder in the foil, are improvers of it.

Manures are commonly divided into three claffes, viz. vegetable, animal, and foffil.

Vegetable manures are whole plants, or parts of them, ploughed into the land, while in a growing ftate, and in full fap; as clover, peafe, vetches, buck-wheat,

wheat, ſea-weeds, &c. and the ſeveral parts of plants, their roots, branches, leaves, bark, and ſeed. Alſo ſaw-duſt, malt-duſt, peat-aſhes, wood-aſhes, and ſoot, rape-duſt, kelp, and vegetable ſalts and oils, &c.

Animal manures are the ſeveral parts of animals, their fleſh, fat, blood, inwards, hair, bones, horns, hoofs; and the dung and urine of animals, horſes, black cattle, ſheep, hogs, pigeons, poultry, rabbits, human ordure and urine, woollen rags, &c.

Foſſil manures, are ſeveral kinds of earth, clay, ſand, chalk, marle, ſhells, lime, limeſtone-gravel, common ſalt, &c. All theſe, and mixtures of them, as ſoap-boiler's aſhes, tanner's-bark, lime rubbiſh, &c. are found uſeful for improving and enriching of land.

Rich loams conſiſt of a due proportion of clay or ſtrong earth, and ſand. They are of a crumbly, mellow, flexible nature, and easily tilled: they are not subject to the imperfections of other soils, to cake, burn, or parch, with drought or heat; nor to poach after rain: but constantly retain a degree of moisture sufficient for vegetation; but not so much as to obstruct the plough, or stick to the shoes in walking over them immediately after rain. Such soils, being naturally fertile, require little or no manure, or superinductions of any kind; but may, with proper tillage and cropping, be kept in a continued state of fertility.

Most sorts of land that deviate from the constitution of the rich loams, may be brought to resemble them by mixtures of other earths. Clays, and very strong lands, are brought into a proper temper by laying on them a due quantity of sandy light earth; and light lands, by laying on clay and strong earth. These are lasting improvements, but they are attended with great expence. The digging

ging, carrying, ſpreading, mixing, and incorporating large quantities of thoſe earths with the land, are too chargeable for common farmers to perform extenſively; for which reaſon they muſt have recourſe to manures and tillage, to reſtore the fertility of their lands, exhauſted by repeated crops. In what manner the different manures operate to produce this effect, is next to be conſidered.

It is a general property of manures, to ferment in the ſoils with which they are mixed. The fermentation excites an inteſtine motion in the ſoil, divides and ſeparates the part of it; which is apparent from its ſwelling and crumbling: the fermentation does not however make any addition to the vegetable food of the ſoil; for that remains the ſame, whether it is divided into many or few parts: but a minute diviſion is an excellent preparation of the ſoil, to receive a new ſupply of the vegetable food from the atmo-

ſphere,

ſphere, which is ſtored with all the variety of matter neceſſary for the nouriſhment of plants. Fermentation therefore opens the ſoil, and multiplies the pores of it: the air, dews, and rain, find an eaſy entrance into theſe pores, and depoſit there the nutritious particles; and at the ſame time render the ſoil pervious to the tender fibrous roots, into the pores of which they extend, and thence collect their nouriſhment.

The vegetable food enters but a little way into the land, unleſs it is opened by tillage or manure; the richeſt ſoils are ſo only near the ſurface; if dug or ploughed deeper than uſual, though the deeper earth is naturally as good as the ſurface, yet it will not produce ſo good crops, till it is opened by tillage or manure; and alſo expoſed for ſome time to the influences of the atmoſphere, and receives from thence the vegetable food. This is a fact generally known to huſbandmen.

Land of a deep ſtaple, that has been ploughed deeper than uſual, requires more than the uſual quantity of manure to keep up its fertility. If tilled to the depth of eight inches, it will require more manure to enrich ſo large a quantity of earth, than it did when tilled but to ſix inches deep; but this additional expence will be overpaid by an encreaſe in the crops.

Fermentation is one of the principal means whereby the earth is enriched, and is not the effect of manures only, but is excited in ſome degree, by every change in the temperature of the air; by heat, cold, dryneſs, or moiſture, the particles of the ſoil are put in motion, divided, and new pores or cavities opened, into which the nutritious aliment is depoſited from the atmoſphere. Without ſuch a continual ſupply, the earth would ſoon be reduced to a ſtate of barrenneſs; as the plants that grow upon it are con-

constantly draining it of the vegetable food.

But though manures act principally by fermentation, they may, and probably do, operate in other different ways upon the soil, whereof no certain account can be given, as we are not furnished with experiments necessary to determine them, for notwithstanding the general use of manures, the practice of farmers in that respect, and their observations upon their effects, are by no means sufficiently accurate to establish any just theory. Yet, of such importance to agriculture is the knowledge of manures, their natures, and manner of operation, that an enquiry into them, so far as we have facts to proceed upon, cannot here be wholly omitted. We shall therefore consider what some of the most ingenious modern authors have said upon this subject, and take notice how far their theories appear to be well founded, or seem defective.

Not however with an intention of determining positively upon this abstruse subject, but in some measure to pave the way for future experiments.

The principal difficulties in relation to the operation of manures, are concerning the vegetable and animal kinds, which, if they could be clearly determined, would in a great measure determine the rest. That they all excite a fermentation in the soil, as above described, is generally admitted; the difficulty lies in determining whether they have any other considerable effect, and enrich it by furnishing the pabulum, or food, by which the plants that grow therein are fed and nourished.

When land is manured with vegetables, or with the parts, or dung of animals, they ferment and putrify therein, and by the putrefaction they are dissolved, and reduced to their first principles. These manures are found to be

great

great fertilizers of land, and as their principles are ſuppoſed to be of the ſame nature with thoſe of the plants that grow upon the land, and that they are much nouriſhed, and encreaſe in growth, by the application of theſe manures, it is concluded that the plants are fed and nouriſhed by the diſſolved principles of of the manure; and that the ſalts and oils of the putrified manures, are abſorbed by the roots of the growing plants, and aſſimilated to their ſalts and oils.

This appears to be a probable theory, and in confirmation of it, it is found, that many roots of plants cultivated in kitchen gardens, that have been much dunged; are tainted by the dung, and have a rank taſte: and M. Duhamel gives an inſtance of the ſeed being alſo ſo much tainted by human ordure, that horſes refuſed the oats that grew upon a field manured with it.

There are however ſome material objections to this opinion of the operation of theſe manures, which ſhall be taken notice of, after reciting the opinion more particularly, as ſtated by ſome of the ingenious ſupporters of it.

"Manures, ſays Mr. Dickſon, operate in all the different ways by which vegetation is promoted: they operate by communicating to the ſoil, with which they are mixed, the vegetable food which they contain—by communicating to it a power of attracting this food in greater plenty from the air—by enlarging the vegetable paſture which it contains—and by diſſolving the vegetable food, which it is already poſſeſſed of, and fitting it for entering the roots of plants.—If the qualities of dung are conſidered, it will appear, that it promotes vegetation in all the different methods mentioned.

"While

"While bodies are in a ſound ſtate, their parts adhere firmly together, and they are incapable of being turned into the parts of other bodies. To render them capable of this, they muſt be reduced to their firſt principles. This is done by corruption. It is obſerved, that by corruption, all the parts of bodies are relaxed, and the ſalts, oils, and other juices which they contain, from being fixed, are made volatile."

"It is, ſays Dr. Hunter, of great moment, to fix upon what is really the nutriment of vegetables, as it will enable us to conduct our compoſt dunghills upon juſt and rational principles. The doctrine of manures is but little underſtood. The farmer ſhould at all times retain in his memory a general idea of them. He may divide the manures into four kinds.

"1. Such as give nouriſhment only, as rape-duſt, ſoot, malt-duſt, oil-compoſt, blood-compoſt, pigeon's-dung, and all hand-dreſſings.

" 2. Such as give nouriſhment, and add to the ſoil; as horſe-dung, cow-dung, human ordure, rotten animal and vegetable ſubſtances.

" 3. Such as open the ſoil, and do not nouriſh in their own nature; as lime, light marles, ſand, and vegetable aſhes.

" 4. Such as ſtiffen the ſoil, and at the ſame time nouriſh a little; as clay, clay-marles, and earth.

" We cannot pay too much attention to every thing that relates to manures; without their aſſiſtance, the richeſt ſoils would ſoon be reduced, by frequent cropping, to a barren ſtate. It is pleaſing to obſerve, how the diſſolution of one body is neceſſary for the life and increaſe of another. All nature is in motion. In conſequence of the putrid fermentation that is every where carried on, a quantity

tity of vegetable nutriment aſcends into the atmoſphere. Summer ſhowers return much of it again; but part falls into the ſea, and is loſt."

"Were vegetables, ſays Dr. Home, to be deſtroyed, only by external force, by far the greateſt part of them would remain untouched, and ſo be an uſeleſs burthen on nature. Were they to be deſtroyed by an internal fermentation, as at preſent, without having their parts volatilized; the particles to which they muſt be reduced, would be continually waſhed off from the ſoil, carried into the ſea, and ſo be of little uſe towards the nouriſhment of other plants.

"The only proper and wiſe ſcheme is followed, the oils and ſalts, from being fixed, are volatilized, and carried up into the air, and deſcend again to fructify the earth."

There is no doubt that the ſalts and oils of vegetable and animal manures, are volatilized by a putrid fermentation; and it is the common opinion that they are thus fitted to enter the roots of plants for their nouriſhment: but if they are carried up into the air, and the earth is not fructified by them, till they deſcend again; of what benefit will this be to the field upon which theſe manures were laid? The farmer will have little reaſon to expect the return of theſe volatile particles, to the ſpot from whence they aſcended; but on the contrary, he may be almoſt certain, from their volatility and extreme lightneſs, that they will be divided and ſcattered in the atmoſphere to a great diſtance; and though by an alteration in the temperature of the air, they do deſcend again upon the earth, with the dews and rain; unleſs they fall upon his land, and upon that particular ſpot he had manured with labour and expence, they will be of no advantage to him.

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This opinion, however, of the earth being fertilized from the atmoſphere, agrees with Mr. Tull's theory, which is the moſt unexceptionable theory of vegetation, that has been offered to the public. Yet, I know not how it has happened, that it has by ſeveral ingenious perſons been miſunderſtood, and by the above quoted authors in particular. And as this is a matter of importance, I hope the reader will excuſe a digreſſion, in order to explain it.

Mr. Dickſon, ſays, that " Mr. Tull has endeavoured to prove, that earth is the food of plants, and hence infers, that to divide the earth into minute particles, by which it is fitted for entering their roots, is all that is neceſſary in agriculture; and this he aſſerts may be done by tillage, without manure. But it is abundantly evident, that other principles, beſides earth, are in the compoſition of this food; and if this is true, the want of of manures, which provide theſe other principles, cannot be ſupplied by tillage. Suppoſing we allow, with Mr. Tull, that earth is the food of plants, yet ſtill it does not follow, that tillage may ſupply the place of manures. It is certain that every particle of earth which we obſerve, is not of the kind that is the food of plants. Every ſoil is a compoſition of different earths, ſeveral of which, it is obvious, are not of this kind."

"The ingenious Mr. Tull, and others, ſays Dr. Hunter, have contended for earth being the food of plants. If ſo, all ſoils, equally tilled, would prove equally prolific. The increaſed fertility of a well pulveriſed ſoil, induced him to imagine, that the plough could ſo minutely divide the particles of earth, as to fit them for entering into the roots of plants."

That theſe gentlemen have miſtaken the theory, may appear from the follow-obſervations.

1. Mr.

1. Mr. Tull, ſays, that manure is not neceſſary in the new, or horſe-hoeing huſbandry, particularly for corn: which he proved by his own practice; and has ſince been fully confirmed by the experience of other ingenious cultivators. But he does not deny the benefit of manure in the common huſbandry, but aſſerts the neceſſity of it. Thus, p. 19, he ſays, " A conſiderable quantity of dung is ſo neceſſary to moſt corn-fields, that without it, little good can be done by the old huſbandry, &c." See alſo, p. 211, 261, and ſeveral other places, to the ſame purpoſe.

2. He ſuppoſes that earth is the food of plants, but does not exclude other principles: for in treating on this point, he ſays, p. 14, " And earth is ſo ſurely the food of all plants, that, *with the proper ſhare of the other elements*, which each ſpecies of plants requires, I do not find but that any common earth will nouriſh

riſh any plant." He thought that earth was the vegetable food principally, as being the moſt ſolid and fixed principle of plants, but he does not therefore exclude the reſt, any more than Dr. Home, who ſuppoſes nitre is that food; or Dr. Hunter, who thinks it is oil; but neither of theſe gentlemen exclude other principles.

3. He ſuppoſes the vegetable food to conſiſt of exceeding fine particles, which adhere to the ſides of the pores or cavities of the ſoil, and theſe cavities he calls the *paſture* of plants, becauſe from them the roots collect the vegetable food lodged there. Tillage divides the ſoil, multiplies its cavities or pores, and opens a communication between them, whereby the roots have a free paſſage through the ſoil. The effect, therefore, of tillage is to enlarge the *paſture* of plants, but does not encreaſe the *food* itſelf. On the contrary, the more perfectly land is

tilled,

tilled, the ſooner it will be exhauſted of its vegetable food, by the roots extending more freely therein; unleſs it is ſupplied with new vegetable food elſewhere. This freſh ſupply it receives from the atmoſphere, and receives it in proportion to the goodneſs of the tillage, and frequent repetition of it, at proper times and ſeaſons. "It has, ſays Mr. Tull, p. 23, been often obſerved, that when part of a ground has been better tilled than the reſt, and the whole ground conſtantly managed alike afterwards, for ſix or ſeven years ſucceſſively; this part that was but once better tilled, always produced a better crop than the reſt, and the difference remained very viſible every harveſt.

"One part being once made finer, the dews did more enrich it; for they penetrate within, and beyond, the ſuperfices whereto the roots are able to enter. The fine parts of the earth are impregnate

pregnate throughout their whole ſubſtance, with ſome of the riches carried in by the dews, and there repoſited; until, by new tillage, the inſides of thoſe fine parts become ſuperficies; and as the corn drains them, they are again ſupplied as before. But the rough large parts cannot have that benefit; the dews not penetrating to their centers, they remain poorer."

And, p. 63, ſpeaking of ſucceſſive crops of wheat, obtained by the new huſbandry, without manure, he ſays; "If it ſhould be demanded, from whence the ſoil can be ſupplied with vegetable matter, to anſwer what is carried off, by theſe conſtant crops of wheat, that the land be not conſumed by them: he anſwers, the ſoil in this our caſe, cannot be ſupplied in ſubſtance, but from the atmoſphere." And then he proceeds to ſhew, how the vegetable food is encreaſed, in well tilled land, by the dews, rain,

rain, &c. that descend upon it from thence.

The earth, therefore, that he says is the vegetable food, is not the common crude earth, but such as has been prepared in the atmosphere. Nor did he imagine, that the particles of the earth could be so minutely divided by the plough, as to fit them to enter into the roots of plants; but says, p. 15, "As to the fineness of the pabulum of plants, it is not unlikely that roots may insume no grosser particles, than those on which the colours of bodies depend; but to discover the greatest of those corpuscles, sir Isaac Newton thinks will require a microscope, that, with sufficient distinctness, can represent objects five or six hundred times bigger than, at a foot distance, they appear to the naked eye." Such a degree of minuteness, as is impossible to be attained by so rough an instrument as a plough.

I ſhall mention only one more inſtance of the miſapprehenſion of Mr. Tull's ſyſtem, by Dr. Home, p. 40, "That the communication of the earth, ſays he, by the mechanical action of the plough, is not the chief means of increaſing the vegetable matter, as Tull aſſerts, appears plainly from theſe two facts; that even the lighteſt ſoil is the better of fallowing; and that when fallow ground is laid up in ridges, more benefit is received than when it is left quite flat."

The mechanical action of the plough, and good tillage in general, prepares the earth to receive the vegetable matter, and ſo far is the means of increaſing it; but the increaſe of it is not the immediate effect of ploughing, but of the influences of the atmoſphere; and this is what Mr. Tull aſſerts. The doctor's two facts produced againſt Mr. Tull's Theory, are the very ſame he has inſiſted upon in ſupport of it. He has ſhewn at large, the

the benefit of frequently ploughing light land, in order to prepare it for receiving the vegetable matter from the atmosphere: and proves from reason and experience, that laying land in ridges makes it more susceptible of that matter, than laying it flat; because when laid in ridges, a larger surface is exposed to the atmosphere. The mistakes made in this matter, seem to have arisen from not distinguishing what Mr. Tull has said of the *food* and *pasture* of plants; or perhaps from perusing some imperfect edition of his husbandry; his original work being very scarce. —But to return from this digression.

As vegetable and animal manures contain the principles of vegetation, salts, oils, &c. and are found to be great fertilizers of land, it is generally thought that they have this effect from their fermenting, putrifying, and dissolving in the soil, and their entering the roots of the growing plants, for their food and nouriſhment; and thus the ſalts, oils, &c. of the dung and other ſuch manures laid upon land, are ſuppoſed to furniſh the ſalts and oils of the crops that grow upon it.

Though this is a plauſible way of accounting for the operation of theſe manures, there are ſome material objections to it. For land is fertilized by pulverization, and the conſequent influences of the atmoſphere, without the ſalts, &c. of manure. This is fully proved by the new huſbandry. The plants cultivated in that way without manure, grow as vigorouſly as if manured with dung; and are found to contain the very ſame principles, and no other, that plants of the ſame kind contain, which are dreſſed with rich manures. This clearly ſhews that the hoed plants receive their nouriſhment, their ſalts and oils, from the atmoſphere, and not from any ſalts and oils originally in the earth. For if any ſuch

ſuch were in it, before this tillage was begun, a few crops would exhauſt them; as we ſee they do the fertility of new-broke land, or land enriched by fallowing; unleſs the fertility of ſuch land is recruited by tillage or manures. But in the way of horſe-hoeing, no manures are neceſſary to recruit the land; but its fertility continues, notwithſtanding the crops produced, and carried off from it every year, ſo long as the hoeing culture is continued.

As it is a fact, that horſe-hoed plants grow as vigorouſly without manure, and contain the ſame principles as manured plants; whether they are manured with any one kind of manure ſingly, or with a compoſition of different kinds; alſo that land dreſſed with manures that contain no oils or ſalts, as marle, chalk, and lime, nouriſh plants as well as if dreſſed with ſuch manures that contain the largeſt proportion of both; it ſeems from hence very probable, that plants receive their nouriſhmenr from the atmoſphere, in one caſe as well as the other; and that the eſſential parts of plants are not communicated to them from manures.

The effect of vegetable and animal manures, and of the hoeing huſbandry, in one reſpect is the ſame: they both open and pulverize the ſoil; whether theſe manures have any other conſiderable effect, is not certain.

It is indeed true, that dung enriches land to a greater degree than tillage; but this does not prove this to be the effect of its ſalts, and oils, in any other reſpect than pulverizing the land: for tillage without manure enriches land; more tillage enriches it to a greater degree; if this land is then dunged, it will be ſtill more highly fertilized. In the firſt caſe, its encreaſed fertility ariſes plainly from its being more pulverized; why therefore ſhould not this effect of the dung be from the ſame cauſe, viz. a further pulverization? for putreſcent manures do, for a time, divide the ſoil more than tillage.

In a dunghill, the putreſcent ferment makes the ſalts and oils of it volatile; and being exhaled into the air, an earth only remains, of no great efficacy to enrich land: if the dung is laid on the land, a fermentation alſo enſues, and the ſalts and oils being there likewiſe volatilized, aſcend into the air; all of them, as ſome think—a conſiderable part of them certainly do; and therefore do not furniſh the crop with any vegetable food; what remains ſeems inſufficient for that purpoſe; ſo that the principal effect of dung, appears to be the breaking and pulverizing the ſoil, by which it is prepared to admit the riches of the atmoſphere.

But ſuppoſing that all the principles of the dung did remain in the ſoil, it is by no means clear that they furniſh the aliment or vegetable food to the crop. To do this, they ought to confift of fuch kind of matter as is fuitable nourifhment to the plants they are to feed. But dung of only one fort is fuppofed to give nourifhment to all crops, to many thoufand fpecies of plants; and all kinds of dung are fuppofed to feed all kinds of plants; though it is certain that the principles of all the various kinds of plants are different, as appears from their different virtues and effects. Hence it feems, that dung would be more likely to poifon many plants than to nourifh them.

To folve this difficulty, it is faid, by thofe who contend that dung and other animal and vegetable manures are the food of plants; that plants have a power of altering their food into their own nature; that they can change alkaline falts into acid, and oils of different natures into thofe of their own; and it feems by this way of reafoning, that plants could change

change ſalts into oils, or oils into ſalts, &c.

This opinion is expreſſed by Dr. Hunter, in his Eſſay on Vegetation and Motion of the Sap, as follows: "We reaſon improperly when we ſay, that every plant takes from the earth ſuch particles as are natural to it. A lemon engrafted upon an orange-ſtock, is capable of changing the ſap of the orange into its own nature, by a different arrangement of the nutritive juices. A maſs of innocent earth can give life and vigour to the bitter aloe, and to the ſweet cane; to the cool houſleek, and to the fiery muſtard; to the nouriſhing grains, and to the deadly night-ſhade.

"The univerſal juice of a plant, is a limpid ſubacid liquor, which flows plentifully from a wound made in a tree, when the ſap is riſing. The birch and the vine yield it in great abundance. This liquor as it moves through the innumer-

able

able ſmall veſſels, becomes more and more concocted, and is the general maſs from which all the juices are derived: it may be called the blood of a plant. By a certain modification it produces high flavoured oils, gums, honey, wax, turpentine, roſin, and even the conſtituent parts of the plant itſelf. How this *tranſmutation* is performed, remains, and perhaps ever will remain, unknown."

This opinion ſeems to imply, that there is but one kind of matter in the univerſe; and the diſtinctions made of different kinds, as of air, water, earth, ſalts, oils, &c. are only different arrangements of it, the ſame matter differently concocted or modified; which is entirely contrary to the received doctrine of original elementary principles, whereof all bodies are compounded: for if there are ſuch principles, eſſentially diſtinct, the nature of them cannot be changed by any arrangement, by their paſſing through the

the veſſels of plants, nor can there be a *real tranſmutation* of elements by any power leſs than His who formed them with theſe diſtinct qualities.

The doctor gives a different account of this proceſs elſewhere: " The air, ſays he, contains, eſpecially during the ſummer months, all the principles of vegetation. Oil for the perfect food, water to dilute it, and ſalts to aſſimilate it. Theſe are greedily abſorbed by the veſſels of the leaves and bark, and conveyed to the innermoſt parts of the plant, for its growth and fructification. When the air happens to be cold and moiſt, this abſorption takes place; when it is hot and dry, the ſame veſſels throw off the ſuperfluous moiſture by perſpiration.

" At the extremeties of the roots of plants, we obſerve a ſpungy kind of excreſcence, pierced with innumerable ſmall holes; through theſe the nutritive juices of the earth are abſorbed.

" The

"The bark and leaves of a plant imbibe at proper ſeaſons the moiſture of the atmoſphere: at other times they perſpire the ſuperfluous nouriſhment."

Here we ſee an ample proviſion made, of oil, water, and ſalt, abſorbed by the leaves and bark from the atmoſphere; and of the nutritive juices of the earth, abſorbed by the roots; plants being thus provided with ſuch abundance and variety of the nutritious matter, from the earth and atmoſphere, why ſhould a *tranſmutation* be ſuppoſed, where it does not at all appear neceſſary to ſuppoſe it?

Dr. Grew, in his curious Anatomy of Plants, gives a clear account of this proceſs of vegetation, and in treating of their trunks, p. 132, expreſſes himſelf as follows;

"If it be aſked, ſays he, how a plant comes to have any oil at all in any part: ſince we ſee that the ſap, by which the root is fed, ſeemeth to be nothing elſe but

but water; and that many plants which yield a great deal of ſtillatitious oil, as mint, rue, and others, will not grow in water: I ſay if it be enquired how this water is made wine or oil? I anſwer there is no ſuch matter: but that the oil, and all other vegetable principles, are actually exiſting in, and mixed *per minima*, though in an extraordinary ſmall proportion, with the water. Even as we ſee the diſtilled waters of anniſe-ſeeds, penny-royal, and the like, to be impregnated with their own oils, which give the taſte and ſmell to ſuch waters.

"I ſay therefore, that all kinds of vegetable principles, are either in, or together with, the water, with leſs difference firſt received into a plant. But when they are once therein, they are there ſeparated, that is to ſay filtered, ſome from others, in very different proportions, and conjunctions, by the ſeveral parts; the watery by one part, the aery by by another, and ſo the reſt; and ſo every part is the receptacle of a liquor, become peculiar, not by any *transformation*, but only the percolation of parts, out of the common maſs or ſtock of ſap. And ſo all theſe parts of the ſap, which are ſuperfluous to any kind of plant, are at the ſame time diſcharged back by perſpirations into the aer."

Hence it appears that the uſe of the innumerable fine veſſels of plants, is not to change the nature of the matter that enters them by the roots or other parts, but to aſſort the particles of them for the uſe of the plant, its growth and nouriſhment.

Here we might conclude this point, but that doctor Home has referred to an experiment, in ſupport of the opinion of tranſmutation, which it is proper to take notice of, experiments being the ſureſt means of attaining a real knowledge of the operations of bodies.

How

" How ſtrong, ſays the doctor, p. 179, the power inherent in the veſſels of plants, to change and alter theſe ſubſtances which are taken in, appears from an experiment of Homberg. He filled two pots of earth mixed with ſome ſalt-petre: into one he put creſſes, which is an alcaleſcent plant, and affords a volatile alkaline ſalt, but no acid; into the other, fennel, which is an aſceſcent plant, and affords an acid on diſtillation, and no alkaline volatile ſalt. He filled two other pots with earth, which had all its ſalts waſhed out, if there were any in it. Into one he planted fennel, and into the other creſſes, as in the former. The two plants in the nitred parts grew much better, and weighed much more than in the pots without nitre. The creſſes in the nitred pot, when diſtilled, gave no acid ſalt, though fed on a ſalt which contained an acid. The fennel fed in the waſhed earth, gave an acid, though there was none

none in the earth. This experiment ſhews, that the veſſels of plants have a power of changing the ſalts taken in from the earth, into their own particular natural one; probably by combining them, with different proportions of water, oil, earth, air, and the particles of light which iſſue from the ſun."

In this experiment, the two plants that grew in the waſhed earth, produced their natural ſalts, one acid and the other alkaline; theſe they received from the atmoſphere, for in the earth there were no ſalts. One of the plants in the nitred earth produced no acid ſalt; though, ſays the doctor, it was fed on a ſalt which contained an acid. But how is the doctor certain that it fed on the ſalt? Did not the fennel in the waſhed earth give an acid; though it did not feed on any ſalt? Whence had it that acid, but from the atmoſphere? And might not the plants in the nitred pots have their ſalts from

thence

thence alſo? The plants in the nitred earth growing much better and weighing more than thoſe in the waſhed earth, is no proof that they fed upon the nitre, and in conſequence thereof grew ſo much the more vigorouſly: for why ſhould this ſalt have ſuch an effect, more than the other parts of their food, their oils, or earth? This will rather be an argument that they did not feed upon the nitre, but that the nitre acted as a manure, and by dividing the earth, and multiplying its pores, as other ſalts and manures do, a larger ſhare of the contents of the atmoſphere was then depoſited, which made theſe plants grow more vigorouſly. And admitting that ſome of the nitre did enter their roots, and none of it was to be found in the creſſes; it is to be obſerved that plants perſpire plentifully, and that they may, as animals, by that means, diſcharge ſuch particles as are noxious, or unſuitable to them.

In the reſearches made to diſcover the nature of the vegetable food, it is uſual to analyſe plants, and earth, ſuppoſing that this food is to be found in one or both theſe. But if plants have a power to alter or change the nature of the ſubſtances abſorbed by them, how is this food to be diſcovered. The doctor made ſeveral experiments upon earth, and ſays, p. 15, 16, that in ſome rich mould he found an alkaline ſalt. If creſſes was raiſed in this earth, it would, upon diſtillation, produce an alkaline ſalt; and fennel raiſed in the ſame earth, would produce an acid ſalt. To what purpoſe then is the examination of the conſtituent parts of earth? The plants raiſed in it will contain their own proper ſalts, however different from thoſe in the earth. The ſame may be ſaid of chemically examining the plants; in ſome are found ſalts of one, and in others of different kinds, but this determines nothing of the vegetable food, of what kind it was, before it was abſorbed by the plants; for the ſame difficulties occur with regard to their oils and earths, as their ſalts.

But it is not neceſſary to proſecute theſe arguments farther, as we have no certain proofs that plants can change the nature of thoſe ſubſtances abſorbed by them, at their roots, bark, or leaves; any otherwiſe than by dividing, aſſorting, or combining them.

In regard to the operation of manures vegetable and animal, and particularly of dung, though the ſort moſt commonly uſed of any, few experiments have been made on purpoſe to diſcover whether it furniſhes the vegetable food, or acts only as a pulverizer of the earth. One has been made, by the author of the Complete Engliſh Farmer, to determine this important point, which he relates as follows;

" Pulverizing the earth, ſays he, p. 117, is not the only uſe of dung, though the following experiments, I muſt own, ſeem to prove it. I cauſed a quantity of virgin earth to be rubbed fine enough to paſs through a ſieve, and then divided it into three equal parcels. I mixed with two of theſe parcels a quantity of dung, equal in weight to one fifth part of their whole ſubſtance; one part with ſtable dung, from a freſh dunghill, the other taken from the bottom of an hot-bed; the third parcel was left without manure, and the ſame weight of earth added to it, as of dung to the other two parcels. The weight of the virgin earth in the two pots mixed with dung, was 15lb. in each; and the proportion of dung was 3lb. in each; the weight of the virgin earth in the mixed pot was 18lb. Thoſe three parcels thus compoſed, were filled into pots of twelve inches diameter, and into each of theſe pots I planted five grains from the

the middle of the ſame ear of wheat, in this quincunx manner ⁚·⁚ , each grain being juſt two inches apart from every other grain, and I planted them with a gage, each one inch and a half below the ſurface of the earth. I was very exact in the ſize of my pots, leſt an increaſe of ſurface, might cauſe an increaſe of vegetable food. Having done this, I placed the three pots upon a level ſpot in my garden, each one foot from the other, on the 7th day of October 1769.

" I marked their progreſs through the winter, and found the ſeeds planted in the virgin earth, more vigorous, and more prolific, than thoſe in either of the other two: the plants in the earth mixed with the rotten dung, were next in vigour and increaſe: but thoſe planted in the freſh dung, though they appeared the greeneſt, and roſe the higheſt at firſt, drooped before the winter was over, ſickened in the ſpring, and before harveſt dwindled to little or nothing. I was prevented from noting the produce of the grain, by the ravage of birds, that almoſt wholly ſtripped the ears; but the increaſe was as follows: from the five ſeeds in the virgin earth, fifty-ſix ſtout ſtalks aroſe: from thoſe in the earth mixed with rotten dung, thirty-five, and from thoſe in the freſh ſtable dung, only twenty, ſome very puny.

" I am ſenſible, however, of the inſufficiency of this experiment on two accounts; the firſt from the want of room in the pots for the roots to ſpread, and collect food for the nouriſhment of the plants; and the other, from not attending properly to ſupply them with water.

" To obviate theſe two defects, I have this year varied my experiments, by encloſing the pots in the ground, preſſing the earth round them, and then taking them out, leaving their exact impreſſion behind, in which I have filled the ſame quan-

quantity of well pulverized earth, mixed exactly in the same manner, as was last year confined in the pots themselves; by which means the tender fibres of the roots, when they have occupied the narrow space contained in the hollow, may now extend themselves on all sides, and collect nourishment. For it may possibly be, that dung by its warmth, and by its fermentative powers, may stimulate the roots, and cause them to extend their fibres to a greater distance than earth, though equally fertile, yet more at rest, may be capable of; and this may be one essential property of dung, and more particularly of fresh dung, withour which it may lose part of its effect.

"A third defect in this experiment, for the purposes intended, might arise from the choice of virgin earth, which has been observed to contain within itself, all the requisites for the production of a single crop. To the increase of this earth, by ſubſtituting an additional quantity of it in the room of dung, the extraordinary increaſe of ſtalks, may probably have been owing; but to remove this objection likewiſe, I have this year filled the pots with earth, from part of a field fallowed for wheat, which has been cropt for two years before, without any dreſſing: ſo that the reſult of this experiment will, to me, be a ſatisfactory deciſion of two very intereſting queſtions to huſbandry: one, whether dung is of uſe only as a divider of the ſoil; the other, whether freſh or rotten dung are the moſt powerful in promoting vegetation. The public ſhall in due time be made acquainted with theſe diſcoveries, if life be ſpared to the writer till the proper ſeaſon."

It is obſervable in this experiment, that the proportion of dung mixed with the earth in the two dunged pots, was a third part of the weight of the earth, which ap-

appears to be much too large a proportion of dung: for if the ſtaple of a field prepared for wheat, is eight inches deep, every foot ſquare of good land of that depth, will weigh about half a hundred weight, and the ſtaple of an acre of ſuch land will weigh about one thouſand eighty-nine tons; now admitting that thirty tons of dung was laid upon this acre, as a common dreſſing, which is a full allowance; yet this would be but a thirty-ſixth part of the weight of the earth dreſſed with it, whereas in the experiment, the weight of the dung was a third part of the earth. And if the ſtaple was ſuppoſed to be of a greater or leſſer depth than eight inches, the proportion of dung in this experiment, would ſtill greatly exceed the quantity commonly uſed for dreſſing land for wheat.

Such an exceſſive quantity of dung, muſt cauſe an uncommon degree of fermentation in the ſoil, more likely to be a

prejudice than an improvement to it; and to this was probably owing in ſome meaſure, the deficiency of the crops in the dunged pots. Hence likewiſe the crops of the pot mixed with ſtable dung, was ſo much inferior to that mixed with rotten dung, becauſe the freſh ſtable dung made a ſtill more exceſſive fermentation.

On the other hand it may be obſerved, that ſifting the earth put into the pots, was a diſadvantage to all the crops, but moſt to that in the virgin earth: for it is allowed by the moſt ſkilful gardeners, that ſifting the earth cauſes it to lie too cloſe, conſolidates it, and obſtructs vegetation. It ſhould be well broke, and the larger ſtones picked out, but not ſifted. The plants in the dunged pots had the advantage in this reſpect, the earth about them was kept open by the fermentation of the dung, and their roots could more freely extend, than thoſe in the

the virgin earth, which had not that aſſiſtance.

Though virgin earth contains in it a conſiderable proportion of the vegetable food; this does not ſeem a ſufficient objection to the uſe of it in ſuch an experiment. The ſame earth was uſed for all the pots, and it ought to be the ſame for all, and no other difference but the dung. If ſuch poor earth was uſed as contained very little of that food in it, it might be too poor to ſupport a crop of wheat till harveſt.

With regard to the additional quantity of earth put into the pot that had no dung, there will be no neceſſity of ſo much, if only the common quantity of dung is put into the other two pots, which need not be more than a thirtieth or fortieth part of the weight of the earth, which will not make any material difference in the crop, whether it be added to the dunged pot only, or if the

ſame

ſame quantity of earth is put into each of the three pots.

And in order to obviate every objection, I would propoſe a variation in the experiment. Let a trench be dug in hard ſtale-ground, four feet wide, and nine feet long, as deep as the ſtaple of the land; break the earth fine, and pick out the larger ſtones and roots of weeds; dig and turn this earth frequently for a year, and ſuffer no weeds to grow upon it. When thus prepared, divide it into three equal parts, lay two rows, or partitions, of bricks, laid flat, and acroſs the trench, as high as the top of it, to prevent the roots getting through them; and at the proper ſeaſon mix the common proportion of freſh dung among the earth in one diviſion, and of rotten dung in another; the third diviſion to have no dung. Plant all the three diviſions with wheat as mentioned in the above experiment, and keep them all clean hand-weeded

weeded till harveſt. Plant but one row of wheat, the grains ſix inches aſunder, along the middle of the piece, and the ſame number of grains in each diviſion.

But if the experimenter does not chuſe to wait ſo long as a year, he may take the earth quite out of the trench, and fill it with virgin, or other proper earth, mixed as before mentioned, with due proportions of rotten and freſh dung, in two of the diviſions.

In this way of planting, no watering will be neceſſary, which when it can be done, ſhould be avoided in ſuch experiments. Rye is not ſo liable to be deſtroyed by birds as wheat, and is proper for ſuch an experiment; but if wheat is planted, it muſt be defended from birds by nets; ſufficiently fine to keep them out. Otherwiſe, as appears from the experiment, and I have always found, there is no guarding againſt the birds without covering the corn with nets, ſo ſecurely that they cannot get through, or under them: and it is material to know, not only the number of ſtems produced, but alſo the fullneſs of the ears and grain.

The experiment thus conducted, will determine which is the moſt proper to uſe, freſh or rotten dung; but I doubt will not determine the other point, viz. whether the effect of dung is only to divide or pulverize the ſoil, or whether it alſo furniſhes the vegetable food to the crop. For ſuppoſe in the above, or other ſuch experiment, the dunged earth produced the largeſt crop; as no doubt it will, if the experiment is in every reſpect rightly conducted; the cauſe of this ſuperiority will be juſtly attributed to the dung, but the manner of its operation will ſtill remain undetermined. This ſhould not, however, deter thoſe who have opportunity, from attempting to diſcover this by experiments, as the know-

knowledge of it is of real importance and ufe in hufbandry.

Of the various fubftances made ufe of by farmers to fertilize their land, there are four that may be reckoned the principal fingle manures, as they are in more general ufe than others, laid on in larger quantities, and they have more lafting effects; thefe are marle, chalk, limeftone-gravel, and lime.

Marle is a foffil body found in the earth, a manure of great value, and many eftates have been very much improved by it. There are feveral forts of it, chiefly the four following, viz.

1. Clay-marle; fo called becaufe it refembles clay, though a very different body. It feels foft and oily, and is found fometimes lying near the furface of the ground, and fome deeper, efpecially under beds of ftrong clay, where it is often found. It is of various colours, red, blue, black, white, and yellow; but the colour

lour is immaterial, being no certain indication of its quality; though many farmers have long thought otherwiſe, founding their opinion upon the colour of marle that they had experience of its goodneſs; and for this reaſon, ſome have recommended the yellow marle as the beſt, others the blue, red, &c. But we have now much more certain methods of inveſtigating them, for which the public is obliged to the ingenious Dr. Ainſlie, who has lately made very curious experiments upon the ſeveral ſorts of marle.

2. Stone marle; which approaches to the hardneſs of ſtone, and is therefore eaſily diſtinguiſhed from the clay-marle, and is of ſlower operation.

3. Slate-marle; this lies in thin layers reſembling ſlate, and is alſo harder than the clay-marle.

4. Shell-marle; which is a compoſition of earth and ſmall ſhells; it is of a lighter ſubſtance than the others, lies

near

near the ſurface of the earth, in low grounds that have formerly been overflowed with water; and ſometimes near the ſea. This is a very rich manure, and of quicker effect than either of the former.

The marles are all compounded of the ſame kind of materials, in different proportions, viz. a calcareous earth, clay, and ſand; and in ſome marles are found ſome ſhining flakes of foliacious talc, unſoluble in acids, and very little altered by fire.

There are ſeveral kinds of earth that reſemble marle, but the following eaſy experiments will diſtinguiſh the true marle from other earths. Firſt put a little freſh dug clay marle into a glaſs, and pour upon it as much water as will cover it, the marle will ſoon diſſolve in the water into a ſoft ſoapy ſubſtance; or if expoſed ſome time to the air, it will fall down into a fine powder. Secondly, marle effervesces with all acids; a little of it put into a glass with vinegar, a brisk motion will immediately be excited, it will effervesce, rise like wine or cyder, and air bubbles will continue to rise, till the acidity of the vinegar is destroyed. Some other kinds of earth will fall down in water or air; but whatever body has this property, and also effervesces with acids, the farmer may conclude to be marle.

It will be of use to farmers not only to distinguish marle from other bodies, but likewise to discover, before they make use of it, what proportion any marle contains of calcareous earth, clay, and sand. This he may readily do in the following manner.—

Having dried and powdered the marle to be examined, pour upon any weight of it a small quantity of water. To this mixture, well shaken, add a little of the acid of sea-salt, and when the consequent effervescence is over, add a little more of the acid. Repeat this addition at proper intervals, till no more effervescence ensues. Then throw the whole, with an equal or greater proportion of water, into a filter of brown paper, whereof the weight is known. When all the fluid parts have passed through, fill up the filter, again and again, with warm water. By this means, the dissolved particles of calcarious earth, adhering to the residue, or entangled in the pores of the paper, will be washed away, and nothing but what is really unsoluble, will remain in the filter. This *residuum*, with the filter, is then to be completely dried, and weighed: the difference betwixt its weight, and the original weight of the filter, gives you the weight of the unsoluble parts (the clay and sand) contained in the marle under examination. This being known, the proportion of calcarious earth therein, is evident.

Here it is to be noted, that a vegetable acid, as vinegar, is not proper for this experiment, becauſe all the calcarious earth in marle cannot uſually be extracted by it: for after the uſual filtration, the reſiduum efferveſces with acids. Neither is the vitriolic acid proper for this uſe: for though it efferveſces with all marles, it does not diſſolve their calcarious earths, but only forms with them a whitiſh coagulum, which will not paſs through the filter. But all the other mineral acids, may be employed to equal advantage; as the acid of ſea-ſalt, nitre, &c.

The proportions of clay and ſand, contained in the *reſiduum* or unſoluble parts of this proceſs, are diſcovered by *elutriation*, which is thus performed. Having weighed the dry reſiduum, mix and ſhake it well, with a ſufficient quantity of water: and after allowing a little time, for the groſſer parts to ſubſide;

let the water, with the fineſt part of the clay ſuſpended in it, be gently poured off, then add more water to the remainder, and after ſufficient mixture and ſubſidence, pour off that likewiſe. In the ſame manner repeat this operation, again and again, till the water comes off perfectly pure; the ſubſtance that then remains is ſand, mixed, perhaps, with ſome flakes of talc; and whatever this ſubſtance wants of the weight of the reſiduum employed, is the weight of pure clay, carried away by the water in this proceſs of elutriation.

This experiment, for diſcovering in marle what proportion it contains of calcarious earth, clay, and ſand, is not propoſed as a matter of mere curioſity; but the farmer who will take the ſmall trouble of examining marle in this manner, may thereby know for which of his lands the different ſorts of marle is moſt proper: for though marles will fertilize all ſorts of land, yet not equally. Thoſe marles wherein he finds the largeſt proportion of clay, are moſt proper to lay upon his ſandy light land, and thoſe that contain the moſt ſand, for his ſtrong land: the calcarious earth fertilizes both ſorts of land, the light and ſtrong.

It is not only uſeful to examine marles, but likewiſe other ſorts of earth, that have a promiſing appearance of being good manures, ſome of which are highly pernicious to land. Among theſe there is one ſort, often found in the ſame bed with the beſt marle, of a darkiſh lead colour. Inſtead of fertilizing ground, it renders the beſt ſoil incapable of bearing any kind of vegetables for many years; Dr. Home, ſays he has ſeen the ſpots on which it was laid entirely barren three years afterwards, and had heard of its effect continuing, in other places, for a much longer time.

If a piece of it is examined that has not been much expoſed to the air, it differs

fers very much in taſte from marle. Inſtead of the ſmooth unctuous taſte of marle, this body taſtes acid, and remarkably aſtringent. It falls down to a powder in water, like marle; but raiſes no effervefcence with acids, nor in the leaſt deſtroys their acidity, which plainly diſtinguiſhes it from marle. It turns ſyrup of violets red, which ſhews it contains an acid; whereas marle, like all abſorbent earths, gives it a green colour.

The Dr. found by ſeveral experiments, that this body conſiſted of an earthy body like clay, a ſmall proportion of a volatile vitriolic acid, and about an eightieth part of ſalt of ſteel. To this ſalt he attributes the poiſonous quality of this body. If any of it ſhould by miſtake be uſed as manure, he thinks it may be corrected with marle; but this is uncertain; and the beſt way is for the farmer to examine ſuch earths as he ſuppoſes to be marle, and intends to make uſe of for manure, before he lays them on the land. If they do not fall down in water, and effervefce with acids, he fhould reject them.

It may however be of ufe, to try to correct the pernicious effects of fuch earths with marles, as the doctor propofes; or with chalk: for it is not uncommon to find land tinctured with fteel, iron, or other metallic mixtures; and if the ill effects of thefe could be cured or mitigated by marle, it would be a valuable difcovery. Perhaps, as he fuppofes, a confiderable fhare of the good effects of marle in all grounds, may be owing to this fpecial effect, viz. the deftruction of bodies, which, in proportion to their quantity, deftroy all vegetation.

We have a ftriking inftance of the poifonous quality of this lead-coloured earth, that fo much refembles marle, in the Complete Englifh Farmer, who fays he was once enfnared by it.

"In digging a well, ſays he, on the ſide of a clay-hill, the workmen met with a ſtratum of this lead-coloured earth, ten feet deep, and threw up a great quantity of it. As it was near a public road, many farmers caſt a longing eye towards it: they felt it, and as it was unctuous and ſlippery, they concluded it was marle, and I was offered a crown a load for it. I did not then know the diſtinguiſhing characteriſtics, and I concluded, that if it was worth a crown a load to them, to carry away, it muſt certainly be worth more to me, to uſe upon the ſpot. Accordingly I cauſed it to be ſpread plentifully upon an upland meadow, which had received no amendment for many years. It was about Michaelmas when it was laid on, and it had all the advantages of air, rains, and froſt, to mellow it; and indeed it was ſo mellowed, that inſtead of falling into a powder, it ran into a ſoft, oily conſiſt-

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ance, not unlike new churned butter. In the ſpring, when I expected the good effects of it, to my great ſurprize, the graſs wore a dead appearance; here and there a green blade among the faded ſward; but this like the reſt ſoon drooped, and in ſhort the moſt amazing ſterility enſued. None but my own ſervants were made privy to the diſappointment: for I did not chuſe to be laughed at by my neighbours. I was not without hopes, however, of its recovery, but though it is now more than ten years ſince this accident happened, the land on which this poiſonous ſubſtance was laid, has not yet recovered its wonted fertility.

" Doctor Home, attributes its poiſonous effects to the mixture of ſalt of ſteel in its compoſition, and I believe very juſtly: for above this ſtratum of lead-coloured earth, large quantities of iron ore were diſcovered, which, on digging clay in other parts of the hill, were found

here

here and there diſperſed in round lumps, about two or three cart loads in a lump, as if a round hole had been dug, and the iron ſtone ſhot into it. Other metallic and foſſil ſubſtances, were found alſo in digging this well; and indeed, when at the depth of ſeventy feet, the water was reached, it was ſo ſtrongly impregnated with ſulphur, that it could not be commonly uſed. I was not, however, aware of the pernicious effects of the blue clay, till I had read Dr. Home's book, where the deſcription of it ſo exactly correſponds, in colour and effects, that I think the doctor's accuracy in deſcribing it, and his candour in cautioning the huſbandman againſt its poiſon, cannot be too much applauded."

From this example may be ſeen the neceſſity of examining untried earths, before they are uſed as manure; and the advantage of having eaſy methods of determining the genuineneſs of marle; one of the moſt capital ſingle manures the farmer has to depend upon.

It ſeems to have formerly been a common opinion, that all rich manures were ſo, becauſe they contained much vegetable food. Hence marle was thought to contain a large proportion of ſalts, &c. but when it was found that it contained no ſalts, it was then ſuppoſed that it attracted them from the air. This likewiſe is now found to be an error; for, from many accurate experiments, particularly thoſe made by Dr. Ainſlie, upon all the marles, that had been long expoſed to the air, he found they contained no ſalts in them of any kind, nor attracted any, except in one inſtance: this he relates as follows—

"Upon the ſurface of ſome marly rocks, which looked towards the north, and had been expoſed time immemorial to the open air, I found a thin white effloreſcence. In many places where water trick-

trickled down from the rocks above, moſs, to the thickneſs of ſome inches, had been in time accumulated, and was now cruſted over with a hard white ſubſtance. Below this cruſt the different plants of moſs were found, diſpoſed in a very regular manner, and ſoldered together by a ſubſtance ſimilar to the cruſt. Here I expected to have found the ſalt of marle, but could not by any treatment diſcover the ſmalleſt indication of it. The mineral acids, after a very briſk efferveſcence, diſſolved entirely both the efflorefcence from the ſurface of the rock, and the matter which adhered to the rock. From this circumſtance it appears, that thoſe ſubſtances conſiſted ſolely of the calcarious earth of the marle, freed from the other earths by the moiſture, &c. whoſe action it had for many years undergone.

"Upon a ſtratum of marle, which, with others, had been expoſed for ages to the open air, I found a whitiſh ſaline efflorefcence, in conſiderable quantity. This efflorefcence was moiſt, and diſſolved readily in water; and alkaline ſalts added to a ſolution of it, immediately precipitated a calcarious earth; after ſeparating the earth by filtration, the remaining liquor afforded, by a proper evaporation, many diſtinſt cryſtals, of a cubical figure; they taſted like ſea-ſalt, crackled in the fire, and by the addition of the vitriolic acid, emitted copious ſuffocating fumes. Hence it appears that the ſalt found upon this marle, conſiſted of the muriatic acid, united to a calcarious earth.

"It is ſingular that no veſtiges of this ſalt appeared upon any of the beds of marle but one, and this one had nothing peculiar, either in its compoſition or ſituation. It differed from the reſt in this only, it was poſſeſſed of a greater degree of moiſture.

"Thoſe

"Thoſe marles were expoſed alone to the air; whether when incorporated with the ſoil, ſuch ſubſtances may be more readily converted, in their calcarious part, into ſalt proper for the nutrition of vegetables, experiment alone can determine. Some circumſtances in the manufacture of nitre, ſeem to perſuade us that they may. On the contrary, obſervations are not wanting, which appear to take greatly from the probability of ſuch an opinion: for marles are found to produce the moſt remarkable effects on light exhauſted ſoils, where they can find little or nothing proper for furthering the nitrous proceſs, or the production of any ſalt we are yet acquainted with. However that may be, I think we are authoriſed by the foregoing experiments (made upon theſe and other parcels of marle) that marle acquires nothing of a ſaline nature, by being expoſed alone to the open air.

"If no ſalt is formed upon marle, from its expoſition to the air, how does

marle

marle operate? An anſwer to this queſtion, would neceſſarily lead us to conſider the operation of manures in general; a ſubject too extenſive and intricate to be diſcuſſed within the narrow limits of this eſſay."

That in one only bed of marle ſalt ſhould be found, though all had the ſame ſituation and expoſure, ſeems to have been from ſome unobſerved circumſtance in that bed; and the obvious concluſion from the whole is, that marle in general does not attract ſalts from the air. The queſtion then, how does marle operate, is, as this gentleman obſerves, difficult to be reſolved. There is however one circumſtance that may in ſome meaſure lead to a ſolution.

It has been obſerved that the particles of marle loſe their tenacity, and fall into powder, in water, and it does not appear that they can be again united, but rather that they have then a repulſive property. This property in marle is very different from

from clay; which though it will alſo diſſolve in water, recovers its adheſive quality when dried; becomes then as hard as before; and will burn into brick, which marle will not; and as marle conſiſts of very fine parts, and theſe are ſo readily ſeparated, they will ferment and incorporate with the ſoil, will open, and very minutely divide it, and by that means enrich it, as was before explained of other fermenting ſubſtances.

Some farmers were formerly of opinion, that ſtrong land was not much improved by marling; probably becauſe they did not beſtow upon it the due quantity of marle; and likewiſe becauſe, as we have ſhewn, that ſome marles having in them a large proportion of clay, are not ſo beneficial to ſtrong clayey lands, as thoſe that abound more with ſand in their compoſition. This is not diſcoverable by the colour and appearance of marle; and farmers did not otherwiſe know how to diſtinguiſh them.

Strong lands, and even clays, are so much opened by marle, that they are made much mellower by it, and drier. And as it opens the ſoil, the ſuperfluous water, which before kept the land cold, finds an eaſier paſſage through it, and and then it becomes warmer, and produces the crops earlier than before. Such are the effects of other manures that open and divide the ſoil, and plainly indicates that this is a principal effect of marle.

In confirmation of this, it is found by experience, that cold, ſour, graſs-grounds, which produce rank weeds, when plentifully marled, the rank weeds are killed, and in their room the white clover ſprings up in ſuch abundance, as if the land had been ſown with the clover ſeed. Some others that are called warm manures, as ſoap-aſhes, &c. have a ſimilar effect. Theſe warm the land by their ſalts, and marle by drying it, which alſo makes it warmer; the effect of of both is to deſtroy the weeds that thrive beſt in moiſt cold ſoils; and encourage the growth of clover, that delights in drier land.

In light land the effect of marle appears to be different. The fault of ſuch land being a deficiency of moiſture, letting the rain paſs too quickly through it, becauſe it conſiſts of too groſs parts, and the cavities of it are therefore too large. The great benefit of marle to ſuch land, ſeems to conſiſt in its fineneſs and very minute parts, which partly fill the cavities of the light land, makes it retain more moiſture, and therefore cools it. What confirms this operation of marle is, that, in general, clays, and all ſtrong earths, have in them the largeſt proportion of fine particles; and all ſuch earths are allowed to be great improvers of too light, dry, warm lands. I might add as a further confirmation of this effect of marle, that theſe light lands are much improved by frequent and thorough tillage, which breaks them into ſmaller parts, and makes them lie cloſer; by which means their cavities are made ſmaller, they better retain the dews and rain, and are evidently rendered thereby cooler, and more fertile: and as marling theſe lands has the ſame effects, the cauſe is moſt probably the ſame.

Stone and ſlate-marles being harder than clay-marle, are longer in diſſolving, and their effect ſlower than clay-marle, for which reaſon a larger quantity of them ſhould be laid on the land, about thirty-five cart-loads, or more, to the acre, and of clay-marle, about twenty-five or thirty loads. Shell-marle being a ſtrong manure, but of an open, looſe contexture, and of quick operation, ten or twelve loads may be ſufficient. If too much of it is laid on at once, it will raiſe a ſtrong fermentation in the land, and cauſe it to ſwell ſo much, that the plants

will

will be in danger of being turned out of the ground, or lodged; and as the nature of the land and other circumſtances are various, it is ſafeſt to lay on this, and all the marles, moderately at firſt: and afterwards, if found neceſſary, the quantity may be encreaſed.

Marle is apt to ſubſide or ſink down in the land, below the operation of the plough; and for this reaſon ſome have adviſed to lay it on the ſurface, or plough it in very ſhallow. But it is better to plough it in to a moderate depth, well mix and incorporate it with the land; and in a few years it may be brought up again near the ſurface, by ploughing the land a little deeper than ordinary. The beſt time to lay it on is between Michaelmas and Chriſtmas, that it may be mellowed by the rains and froſt, and when thoroughly broken, ſpread it very even upon the land before it is ploughed in. A good dreſſing with marle, will very much improve the land for fourteen or fifteen years.

Sometimes marle lies ſo near the ſurface of the land, that the farmer may find it in the ſides of his ponds and ditches, but more frequently by boring the land with a common two or three inch auger, that has a jointed ſtem, eight or ten feet long. Such an inſtrument is very proper to diſcover marle, clay, peat, or other ſoft earths, that do not lie at a great depth. It ſhould be drawn up often, and the earth it brings up examined, and cleared out. But when the harder deep foſſil earths are to be ſearched for, another inſtrument is to be uſed, ſuch as is recommended by the marquis de Turbilly, from long experience of its uſe. It is a round iron rod, about an inch in diameter, made in joints each about three or four feet long, and to ſcrew one into another. At the bottom of the lower joint is ſcrewed in a ſtrong blunt ſteel point,

point, and a little above that, there is a groove made in the rod, near half an inch wide, and deep, and four or five inches long. There is likewiſe an iron handle to go acroſs the rod, and faſten to it, but ſo that the handle may ſlide up and down upon it; ſeveral ſmall holes are made through the rod, and one through the handle, and by putting an iron pin through both, the handle may be confined to the rod, higher or lower as ſhall be found neceſſary. The handle is to draw up the rod by, and being thus faſtened, prevents its ſlipping down out of the hand, and being loſt.

When this borer is to be uſed, begin with one or two joints only; it is to be lifted up, and let fall perpendicularly upon the place where it is to enter the ground, which it will do by its own weight, a little way at firſt, and ſtill deeper every time it is lifted and let fall down in the ſame hole. When it has penetrated to the top of the joint, ſcrew another on, till it has gone as deep as required. As it will penetrate ſome inches deeper at every ſtroke, the groove at the bottom ſhould be often ſearched, and the earth taken out of it, put into papers, and numbered; by which will be ſeen, as the rod deſcends, what kinds of earth lie, at different depths, below the ſurface; and is of excellent uſe for diſcovering marle, chalk, lime-ſtone, coal, fuller's-earth, tobacco-pipe-clay, and other valuable earths and foſſils fit for manure and other purpoſes, where it was not ſuſpected that there were any ſuch; for, as that excellent huſbandman, ſir Digby Legard, has obſerved; "I cannot, ſays he, help thinking, that every ſoil either contains within itſelf a remedy for its original barrenneſs, or, at leaſt that no large tract of country is deſtitute of ſome peculiar productions adapted to its fertilization, ſo as to render it fit for the

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production of vegetables, and the support of animals—But the treasures of nature are not always obvious, nor her productions spontaneous." This kind of borer, has, by still adding more joints, gone to the depth of an hundred feet, and will penetrate into beds of slate and stone marle, and even into lime-stone, and stone of other kinds. The expence of boring is not much, as one man can bore with such a rod forty or fifty feet deep, which if done every four square perches, may be sufficient, or if thought proper to go deeper, and the borer is, for strength, made thicker, it may be worked by two men.

If it is desired to know whether there are any springs in the ground, a little dry spunge put into the groove, will discover them, and at what depth they lie; for the spunge will be made wet in passing through them. This is of use to be known, when wells are intended to be dug,

dug, or lucern and other deep rooting plants are proposed to be planted, that will not live where their roots reach water.

Chalk is another valuable manure, found in several counties of England in great plenty, but little or none of it in Scotland, nor in Ireland. It is a fossil body, consisting chiefly of a calcarious earth, and readily burns into lime: some of it is of a soft, soapy quality, which is reckoned the best for manure: it is somewhat of the nature of marle, and is called so in the Isle of Wight. It is often found near the surface of the ground, lies in beds as free-stone, and frequently to a great depth.

Chalk is in general of a dry quality, and consists of very minute parts, and hence it seems to be so great an improver of clayey and other lands. When dried by the sun and air, it will not fall down into powder among water, as marle does, but

but becomes almoſt as hard as ſome kinds of ſtone: for this reaſon it ſhould not be dug and expoſed to the air in ſummer. The beſt time to dig it up is in the beginning of winter, from Michaelmas to Chriſtmas, and to carry it upon the land as ſoon as dug; for then it is moiſt, and will diſſolve by the rain and froſt; but will not diſſolve in a long time, if ſuffered firſt to become dry and hard. When laid on the land, the large pieces ſhould be immediately broke ſmall, and ſtill as it diſſolves ſhould be evenly ſpread upon the land, and ploughed in. If this is done carefully, the whole will be fit to plough in by Candlemas; but none of it ſhould be ploughed in till thoroughly broke: and the whole ſhould be well mixed with the land by ploughing and harrowing.

About thirty cart-loads of chalk, thus managed, will be a moderate dreſſing for an acre of ſtrong land, which it will enrich for fourteen or fifteen years. But, like marle and ſome other manures, chalk ſubſides through the ſoil, till it gets below the tillage, and may be found lying there in a thin cake. By ploughing the land a little deeper, the chalk is again brought up, and will have the ſame good effect as before.

It is cuſtomary with ſome farmers to mix dung with chalk, when firſt laid on; and others give a dreſſing with dung, every fourth or fifth year after chalking; which without doubt adds to the fertility of the land. But if the chalk is prepared as above mentioned, and a ſufficient quantity laid on, ſuitable to the quality and condition of the land, no dung will be neceſſary at firſt, nor till the land begins to abate of its fertility, which after ſome years it will do, by part of the chalk ſinking down below the action of the plough, and the effect of ſo much of it being thereby loſt, till the whole

whole is brought up again. For this reaſon it is neceſſary to add more chalk, to ſupply the room of what ſinks down, or to ſupply that deficiency with dung, till the chalk is all to be ploughed up again.

Chalk has been long uſed as a great improver of clays and ſtrong loams, and thought to be improper for light land; but it is now found by experience to enrich all ſorts of land, the light as well as the ſtrong. To underſtand the reaſon of this double effect, I ſhall refer the reader to what is ſaid of marle. Chalk, like marle, opens and mellows clays, and conſolidates light ſoils. Not becauſe it contains any of the vegetable principles, as ſalts, &c. or that it attracts them from the air. For pure chalk is naturally barren, and no ſalts are found in it. The author of the Complete Engliſh Farmer, indeed ſuppoſes, that chalk contains in it the principles of fire, becauſe it warms

cold

cold clay ſoils: but it gives no indication of its containing fire more than other calcarious earths; its warming cold wet land, being in conſequence of its opening ſuch land, by which the water eſcapes which ſtagnates in ſuch land, and is the cauſe of its coldneſs. And beſides, if chalk, had this effect upon cold land, by reaſon of its heat, it would be pernicious to light hot land, contrary to experience.

That the improvement of ſtrong clayey land by marle and chalk, is from their drying and warming ſuch land, appears from hence, that all ſorts of land, ſtrong and light, are made cold and impoveriſhed by wet or too much moiſture; and that they are conſtantly improved and made warmer by draining, or opening manures. Ruſhes, flags, ſedge, horſe-tail, and other ſuch plants, thrive in ſtrong and light lands, if water ſtagnates in them; becauſe that keeps them moiſt and

and cold; but let the ſuperfluous water be, by any means, carried off, they will die away.

Lime is another manure of general uſe, and is made from chalk, and from lime-ſtone, whereof there are different ſorts: the hardeſt makes the ſtrongeſt lime. Lime-ſtone contains a large proportion of calcarious earth, which is of a fertilizing quality: for unburnt lime-ſtone reduced to powder, is a good manure. But many kinds of ſtone have little calcarious earth in them, and theſe will not burn to lime. The way to diſcover lime-ſtone, is to pour a little of a mineral acid upon the ſtone to be examined, as oil of vitriol or aquafortis, and if a briſk ebulition enſues, it may be concluded to be lime-ſtone: for theſe acids have no ſuch effect upon any ſtone that will not burn into lime.

There are different opinions concerning lime, ſome highly commending it as an excellent manure; others condemning

it

it as a great impoveriſher of land. The laſt quoted author ſays, " That lime laid on, at whatever time, or managed in whatever manner, will, after the firſt or ſecond year, impoveriſh every ſoil it mixes with. Four years ago, ſays he, upon a hilly field of clay, I limed for wheat, at the rate of ſixty buſhels upon an acre; and by the perſuaſion of my ſeedſman, I ſowed near three buſhels of wheat, and reaped after the rate of ſixteen. The year following oats were ſown upon the ſame field, not through choice, but from neceſſity, and produced about four quarters upon an acre. The third year, barley and clover, after being winter fallowed and ploughed thrice; the barley did not amount to five buſhels, and hardly a blade of clover was to be ſeen when the barley was mowed, though ſowed at two different periods, both favourable enough, as being ſown when the ground was moiſt, and rain ſucceeded in a few a few days after ſowing. The abſolute ſterility of this field, I wholly impute to the effects of the lime; which though as a manure I decry, yet as a preſervative againſt the ravages of grubs and inſects, I moſt zealouſly commend. Neither is there any bad effects to be apprehended from the moderate uſe of it. Ten or fifteen buſhels ſown upon an acre by hand, in ſuch a manner as to be all equally diffuſed, will warm and cheriſh land, when ſixty ſpread with a ſhovel, will hurt and impoveriſh it. This caution I thought proper to repeat, becauſe of the indiſcriminate uſe, which the beſt farmers are too apt to make of this manure."

The ill ſucceſs of this experiment, ſeems to have been the principal reaſon of the auther's decrying the uſe of lime, for in the preceding paragraph he ſays, "In Suſſex, which runs much upon ſtiff clay, and all through the North, they always prepare their lands for wheat, by manuring with lime; and though I do not approve of the practice, from the ill success that has attended my own experiments, yet I cannot believe that it would be universally followed in those countries, if it were discovered to be universally hurtful. Indeed they fallow and lime for wheat; and as no one ventures a crop upon fallow alone, all the merit of the increase, is placed to the account of the lime."

This gentleman's clay-field seems to have been a poor soil, or not in good heart; and the succession of his crops was unfavourable to his experiment; three robbing crops in immediate succession, without any other help than sixty bushels of lime per acre, must impoverish the land; and sixty bushels was too small a quantity to lay upon clay, especially if it was chalk lime, which is the weakest sort.

As to their practice in Yorkshire, where they use much lime, Mr. Young, says,

" Is to lay a chaldron and half per acre, thirty-two bushels per chaldron, on summer fallows, either for turneps or wheat. But Mr. Crowe, instead of this practice, has substituted another, which he finds greatly advantageous, and in which thought I believe he is original. It is to throw a chaldron per acre every year, over all the land of his farm, before winter, and plough it in, whether for a crop or a fallow. This he finds to be of excellent service, in mellowing the land with the spring frosts, and dries it in such a manner, that all his lands are, by this means, ready much sooner in the spring for ploughing: an effect which is undoubtedly of great consequence, as it accelerates an early sowing, so important in all crops. The farmers in this neighbourhood, lay from one, to two chaldrons and a half per acre, and find it very beneficial to all sorts of land—The soil here is of two sorts, a loamy gravel, and a cold wet red clay. Mr. Crow's ſoil is gravel and clay, but his arable fields all clay."

In other parts of this country, they lay from one to two, three, four, and ſometimes five chaldrons of lime upon an acre. I have known three hundred ſtrike, Wincheſter buſhels, of ſtrong ſtone-lime laid upon the acre of clay ground, and once above that quantity upon a poor lay; which being ploughed in, and the land ſown with wheat, the conſequence was, a luxuriant, lodged crop. Where lime is cheap, it is common to lay a buſhel upon every ſquare perch of land, or an hundred and ſixty buſhels per acre. But when ſuch large quantities were laid on at once, it is for ſeveral years, and the land to have no other dreſſing: but Mr. Crow's method of liming every year in ſmaller quantities, is to be preferred. And though in a courſe of years, the annual repetition amounts, upon the whole,

to

to a large quantity, it is plain from his ſucceſs, that lime is very beneficial, even to very ſtrong land.

" It is, ſays Dr. Hunter, generally ſaid, that lime anſwers better upon ſand than clay. This obſervation will undoubtedly hold good, as long as the farmer continues to lime his clay lands in a ſcanty manner. Let him treble the quantity, and he will then be convinced, that lime is better for clay than ſand. It may be juſtly anſwered, that the profits will not admit of the expence—I agree. —But then it muſt be underſtood, that it is the application, and not the nature of the lime, that ſhould be called in queſtion. Clay well limed will fall in water, and ferment with acids: its very nature is changed.

" Lime mixed with clay comes neareſt to the nature of marle, of any factitious body we know of, and may be uſed as ſuch, where it can be had withont

 much

much expence. By increafing the quantity of clay, it will make an excellent compoft for a light fandy foil: but to make the ground fertile, woollen rags, rotten dung, or any oily manure fhould be incorporated with it, fome time before it is laid on."

"Lime, fays another practical hufbandman, is one of my favourite manures; as I have feen it work miracles, and, if properly managed by proportion, never fails its proprietor." The proportion or quantity ufed, is undoubtedly a material circumftance, and fo is likewife the quality of it; the lime made from marble, or very hard ftone, being abundantly ftronger than chalk lime.

Strong clayey lands are very improveable by liming, but the moft general prac- is to lime light, fandy foils, the effect of which is remarkable, efpecially at firft: for it is by many thought to impoverifh them greatly afterwards. Liming them

a fea ſecond time has but little effect, the fertility of the land is exhauſted, and it is at laſt in a much poorer ſtate than before any lime was laid upon it. This effect of lime is differently accounted for. Thoſe who think oils and ſalts mixed with the ſoil, neceſſary to vegetation, acknowledge that lime affords neither of theſe; but they ſay, that there is a great attraction betwixt quick lime and all oily bodies, and therefore lime muſt attract oils powerfully from the air and earth, diſſolve them, and render them miſcible with water. Alſo that lime ſeems to have the property of collecting the acid of the air, which it readily forms into a neutral ſalt, of great uſe in vegetation; hence, they ſay, it is probable that lime tends to rob the ſoil of its oily particles, and in time will render it barren, unleſs the farmer takes care to ſupport it with rotten dung, or other manures of an oily nature. Alſo that the excellency of lime upon a ſandy ſoil, is by mechanically binding the looſe particles, and thereby preventing the liquid parts of the manure from eſcaping out of the reach of the radical fibres of the plants. This is an ingenious theory, but loaded with too many ſuppoſitions. For notwithſtanding the ſuppoſed uſes of oils in the earth, it is upon good grounds queſtioned, whether earth contains in it either oils or ſalts, as appears from many experiments made by the curious in different parts of Europe, Britain, France, Holland, Switzerland, and Sweden, to diſcover from whence vegetables are ſupplied with their food, from water, air, or from earth. Theſe experiments were variouſly conducted, but ſimilar in the event.

Van Helmont planted the cutting of a willow, weighing five pounds, in an earthen veſſel, having a tin cover, perforated with a number of ſmall holes, wherein he put two hundred pound of dried

dried earth, which he watered as often as neceſſary. At the end of five years, he took out and dried the earth, and found it had only loſt two ounces of its original weight; but the willow had gained an hundred and ſixty-nine pounds and three ounces, from the water, or its contents.

Gleditch, Bonnet, and Du Hamel, found, that plants ſet in moſs or ſpunge, kept in glaſſes, moiſtened with water, grew well and flouriſhed, without earth, and that theſe plants contained the ſame principles, as other plants of the ſame ſort, which grew in earth. And that mixing the water with nitre, common ſalt, and even with a ſolution of rich earth or dung, contributed little to the growth of plants, and that that they throve better in pure water.

G. W. Kraft, ſowed oats and hemp-ſeed in different ſubſtances, viz. in rich earth, dried ſand, in pieces of woollen cloth,

cloth, and chopped hay: he moiſtened theſe ſeeds with water, and found they grew nearly as well in one of theſe ſubſtances as in the other. But in filings of iron, in aſhes of plants not waſhed, in ſand mixed with nitre, in pot-aſhes, and in flour, though ſown and treated in the ſame manner, they did not vegetate at all. Dr. Alſton, made nearly the ſame experiments, with the ſame ſucceſs. Salts of ſeveral kinds mixed with earth, not only retarded the growth of plants, but put a total ſtop to it. He found that the moſt hungry earth, exhauſted by vegetation, and ſifted, nouriſhed plants full as well as the richeſt earths. He alſo remarked, that the hungry earth became much more barren, by being mixed with lime, and that lime water did not promote the growth of herbs or ſhrubs.

"From theſe experiments, ſays Wallerius, made with the greateſt care, repeated with the utmoſt circumſpection, and

and always attended with the ſame ſucceſs, we are authoriſed to conclude, that the earth yields no real nouriſhing matter to plants, but that their nutritive juices, are derived from water and the atmoſphere.

" Trieiwald, in Sweden, and ſince him Eller, have alſo lately confirmed theſe experiments. The latter obſerved, that the roots of hyacinths, put in diſtilled water, not only produced perfect plants, but, after being burnt, yielded true earth.

" Theſe experiments prove evidently, that vegetables derive all their conſtituent parts from water, and air, and even their oils and ſalts, as well as their earthy particles; as will appear ſtill more plainly from what follows.

" Four thouſand different plants can grow in twenty pound weight of earth; and in each of them ſhall be found a different oil, and a different ſalt. Let us ſuppoſe

pose these plants to be chemically analysed; near an ounce of oil and salt will be found in each. If this oil and this salt, had proceeded from the earth, there must have been in that earth four thousand ounces, or two hundred and fifty pounds, of oil and salt; whereas, in fact, there was not a grain of either of them in it."

Upon the whole, the following conclusions appear to result from these experiments, viz.

1. That the great source of vegetable nourishment is from the atmosphere: from thence the earth is supplied with it, and likewise the air and water; for these, when divested of it, are again recruited, and receive a new encrease of it from the atmosphere.

2. As all sorts of earth are liable to be exhausted of the vegetable nourishment, by the plants that grow upon them, and are again replenished with it from the atmosphere;

mosphere; the difference between rich and poor soils appears to consist in their aptness to receive more or less of that nourishment.

3. This aptness or disposition in different soils, to receive from the atmosphere different degrees of fertility, arises from the number, size, and qualities of the particles whereof these soils are compounded.

4. Rich earths are found to consist of innumerable fine particles, which, when opened and divided, by tillage, manure, or the fermentation excited in them, by the vicissitudes of heat and cold, drought and moisture, are thereby prepared to receive large proportions of the vegetable food from the atmosphere: whereas poor earths, containing a great deal of gross parts, stones, gravels, and large sands, not fit to receive the nutritious matter; and of fine particles, a very small proportion, are not adapted to receive or re-

tain the vegetable food in any conſiderable quantity, and are much ſooner exhauſted of it than rich earths.

Hence appears the real ſource of the vegetable food; and points out the manner in which manures do probably operate upon different ſoils to enrich them.

There is no ſort of manure, concerning which opinions have been more different, than of lime; and as it is to be had in many places, it is a matter deſerving particular enquiry, whether lime is of that pernicious quality to land, as by ſome has been repreſented; and the grounds of this opinion.

Lime is reckoned a great forcer of land; the meaning of which is, that lime diſpoſes land to exert a much greater degree of fertility at firſt, than it was before capable of. This is no diſadvantage to the farmer; a few large crops of corn being more profitable, than many very poor ones. But then, it is ſaid, that

after

after producing theſe few large crops, the land is ſo much exhauſted, that it ever after remains incapable of being reſtored, by lime or other manures.

To ſet this matter in a juſt light, it is to be obſerved, that lime has moſt commonly been uſed as a dreſſing, to light, thin, poor ſoils. That theſe poor lands being frequently ſo remote from the homeſteads that the farmers could not ſpare their dung to dreſs them; or thought the expence too great, of carrying their dung to ſuch a diſtance; and therefore choſe to lime ſuch lands; the effect of lime continuing longer, and the carriage much leſs expenſive than dung; as one load of lime will manure as much land, as four or five loads of dung.

In conſequence of a good liming, the farmer expects his poor land will produce him ſeveral good crops of corn, and he proceeds accordingly to crop it every year without intermiſſion, allowing it no pro-

proper change of crops, no fallowing, nor reſt; nor any other manure than the firſt liming; neither does he diſcontinue his crops, when he perceives the land abating of his fertility. On the contrary, too many farmers are apt to run their land out of heart, not only after liming, but in common practice. Nor is the complaint of impoveriſhing land, reſtricted to lime only; the ſame thing has been ſaid of marling, chalking, and more eſpecially of burn-beating, which enriches land greatly at firſt, but by a repetition of exhauſting crops, is often impoveriſhed to as great a degree as land after liming.

The injury to the land therefore, ought not to be charged to liming, but to overcropping, and running the land out of heart. Many inſtances might be given of this; and I have ſeen ſome poor fields, that after liming, had been every year cropped with corn, for a long courſe of years, till they were at laſt incapable

of

of yielding a crop of corn, or even weeds.

Similar to this, Sir Digby Legard describes the bad husbandry practised upon the Yorkshire high wolds. "All the manure, says he, this land gets, is from the sheep-fold, and were he, (the farmer) content to plough no more than he can thus well improve by twice folding, it would be well; but the rage of ploughing is so great, that he every year has been accustomed to plough up a fresh part of his sheep-walk, to take a crop or two, and then let it lie fifteen or twenty years, till the natural grass has again formed a kind of turf: but it will sometimes be forty years before the land is completely sodded over. This ruinous practice is but too common; and where it has long prevailed, the farmer seldom has a threefold increase. He sows four bushels of oats, and three of barley, and is happy if he reaps twelve bushels of the former, and nine of the latter. He may plough half an acre in a day with two horſes; therefore his crop being worth eighteen ſhillings, if we deduct twelve ſhillings for ſeed, tillage, and rent, his profit is ſix ſhillings, but the value of the ſtraw is not equivalent to the expence of mowing, binding, and leading home; two ſhillings ought to be charged for thoſe articles; and thus is his profit reduced to four ſhillings *per* acre."

The rent of the wolds is only one ſhilling *per* acre, and it might be thought that ſuch poor crops were owing to the native poverty of the ſoil; but this is not the caſe: for though it is not indeed rich, yet we find, theſe bad unprofitable crops, are not in conſequence of the poor ſoil, but it is principally owing to the bad huſbandry; as appears by the crops received from ſome of the very ſame land by Sir Digby himſelf.

"I have,

"I have, ſays he, incloſed three hundred acres on the top of the wolds, and have laid down the greateſt part with various kinds of graſſes. Sainfoin, white-clover, rye-graſs, rib-graſs, and burnet, which ſucceed pretty well with me. Theſe graſſes taken at an average, a good year with a bad one, and thirty or forty acres together; yield near a ton of hay per acre, on land which never bore any hay before it was incloſed. I eſteem this land to be now well worth ten ſhillings an acre. Theſe three hundred acres were as bad as any in the lordſhip. I find by experience, that the ſame land in corn yields, after being well manured, three quarters of barley, and two quarters of wheat per acre. My turnips are worth at a medium thirty ſhillings per acre, and the clover twenty ſhillings."

Here we have a ſtriking example of the effects of different management of the ſame land. In one caſe this land produces on an average but nine bushels of barley per acre per annum. In the other, the same land produces twenty-four bushels of barley, or almost three times the quantity it yielded, under the bad management of the tenants of the wolds.

Lime has been most commonly used upon light, poor land, which it has been supposed to impoverish. No such bad effect is usually observed from liming strong good land: for though good land is also subject to be impoverished by bad management; yet, as it contains a large fund of rich materials, it recovers again in a short time; whereas poor land containing a much smaller proportion of such materials, is sooner exhausted, and long in recovering. Lime is undoubtedly a valuable manure for all sorts of land, but the good effects of that and other dressings, depend much upon the conduct of the farmer. He may by bad management run any

any land out of heart, especially poor land; but this ought not to be imputed to liming. The tenants of the wolds impoverished their lands to such a degree, that they did not when rested, form a new turf in fifteen, twenty, and sometimes in less that forty years; what greater injury than this could liming have done? And yet this same land judiciously cultivated, was worth ten shillings per acre rent.

Where a person has occasion to use much lime, he may burn it himself at a much cheaper rate than he can buy it: and his lime may be burnt more perfectly, and will go farther in manuring: for in lime burnt for sale, there is generally a considerable proportion of raw, or half burnt stones, that are of little or no service to the land at first, or are long in dissolving. Lime when thoroughly burnt, falls presently into a very fine powder, which mixes perfectly with the soil, and acts upon it fully from the beginning; but when not well burnt, a greater quantity muſt be laid on the land, and the operation of it is ſlower and more uncertain. For theſe reaſons, lime perfectly burnt, is moſt to be depended upon by the farmer, and is the cheapeſt manuring.

To burn a large quantity of lime at once, mark out a piece of ground with a boundary line in form of a long ſquare. Cut ſeveral narrow parallel trenches lengthways of the ground, and others acroſs the former. The ends of theſe trenches ſhould extend beyond the boundary line. Fill the trenches with bruſh-wood or furze, and lay ſome larger wood acroſs all the trenches. Then lay a layer of coals all over the foundation, and upon that, a layer of lime-ſtone broke ſmall. Upon this lay wood or furze, next coals, and then lime-ſtone. Continue to make layers of theſe to the top of the clamp. In the mean time walls of turf are to be raiſed, all round upon the boundary line; and theſe are to be tied with croſs walls of turf, to ſupport the whole while burning.

ing. Some vent-holes are alſo to be left open near the top of the wall to draw air. And when the wall, and layers within, are raiſed about nine or ten feet high, the top is to be finiſhed in form of the roof of a houſe, and covered with turf. Then ſetting fire to the furze at the ends of the trenches, keep the whole burning with a ſlow fire, till the lime-ſtone is calcined. If any of the turfs fall down, they are to be returned to the clamp. The ſmaller the ſtones were broke, the more perfectly the lime will be burnt, and with the mixture of turf, coal, and wood-aſhes, will make excellent manure.

Lime may be alſo burnt in kilns built with turf, the ſtones broke ſmall, and laid in layers with coals, wood, or furze. Theſe ſerve to burn lime occaſionally, and in ſmall quantities, Theſe kilns ſoon decay, but the expence of erecting them is not much; and they may be made upon the fields where the lime is to be uſed.

But where there is a conſtant demand for lime, it is by much the beſt way to erect a kiln of brick or ſtone. Some are built wide at top, and narrowing downwards towards the bottom: but kilns of this form require much fewel. Such as are narrow at top and bottom, and wide in the middle, called reverberatory kilns require the leaſt fewel, and burn the lime moſt perfectly; and where they are made not to be emptied at once, but ſome of the thorough burnt drawn out at bottom, and filled again at top, once or twice a day, theſe are called perpetual or running kilns, and are the moſt convenient, where large quantities of lime are wanting. The following I have found to be a good form for one of theſe kilns.

Pl. II. Fig. 7. *a*, *b*, is the depth of the kiln eighteen feet; *c*, *d*, the width of the kiln at the top, ſix feet; *e*, *f*, the width at bottom ſixteen inches. The kiln at *g*, *h*, ſeven feet and a half from the top, is is nine feet three inches wide, and continues of the ſame width to the middle at *i, k*. From the middle *i, k*, to the bottom *e, f*, it narrows gradually to ſixteen inches: the form therefore of this kiln is ſomewhat eliptical or oval: from one hundred to one hundred and fifty buſhels of ſtone-lime may be burnt in it every twenty-four hours; twenty buſhels of coals or culm will burn about one hundred buſhels of ſtone-lime, but conſiderably more of chalk-lime. The ſmaller the lime-ſtone is broke, the ſooner it will burn to lime, and the more thoroughly. A kiln of this form reverberates the heat ſtrongly, and will burn lime with much leſs fewel, than thoſe that are wideſt at top.

It may be built of ſtone or brick, and the walls ſhould be between two and three feet thick. If of ſtone, it ſhould be ſuch as will ſtand the fire, without being calcined; the blocks cut regular, and laid in ſtrong mortar. If built with bricks,

bricks, they ſhould be of the beſt ſort. But the violent heat will notwithſtanding cauſe the ſtone and brick to ſcale and break off on the inſide of the kiln; which, if conſtantly uſed will wear away ſo much, that the kiln, in no long courſe of time, muſt be rebuilt. To ſave in ſome meaſure this expence, the beſt way is to line ſuch kilns at firſt on the inſide, with the beſt bricks, laid flat all round it, with their ends pointing to the center of the kiln; and when theſe wear away with the heat, the whole brick lining is to be taken out, and the kiln new lined as at firſt: by this means the walls of the kiln will laſt a great while.

The beſt ſituation for ſuch a kiln, is on the ſide of a hill, or riſing ground, into which it ſhould be built ſo far back, that only the eye, and a ſmall part of the front of it ſhould be ſeen, and all the reſt ſunk into the hill; being thus almoſt ſurrounded with a thick bank of earth, the heat

heat will be confined, and lefs fuel will be neceffary than if the walls of the kiln were naked and open all round.

When the kiln is thus erected, a good fpace of ground at the upper part of it fhould be levelled even with the top of the kiln, and a fhed built there, large enough to receive the coals and lime-ftone, and for men to work in the dry, and break the lime-ftone there.

Kilns that are open and without fhelter at top, are fo much expofed to windy and rainy weather, that the burning is often obftructed, and fometimes entirely ftopped by it; and much rain damages the lime. To prevent this, raife a dwarf wall all round the top of the kiln, except next the fhed, where an opening is to be left, to fill the kiln when neceffary; and the fhed is to be continued quite over the kiln: which being thus fheltered on all fides, may be worked at all times without injury or obftruction from the weather.

A cart-

A cart-way is to be made, winding up the hill with a gentle aſcent to the ſhed, that the lime-ſtone may be carried up there directly from the quarry without being unloaded. Or if there is not room for a cart-way, a narrow road may be made, to carry up the lime-ſtone and coals in wheel-barrows; but this is more tedious and expenſive than to carry them up in carts.

Where there is a demand for large quantities of lime, a lime-houſe ſhould be built adjoining to the eye of the kiln, into which the lime may be conveniently carried, as it is drawn out out of the kiln, without receiving any wet: and is there kept dry, till it is wanted. This method of conſtructing a lime-kiln, ſheds, &c. is the moſt convenient and complete, of any hitherto contrived.

Lime-ſtone-gravel is a manure of general uſe in Ireland, where it abounds. Some of it is alſo found in Britain, and might doubtleſs be found in many places, if if diligent ſearch was made for it. It conſiſts of an earth mixed with ſmall ſtones of different ſizes, which are of a calcareous nature. If laid on the ſurface of meadow or paſture, the ſurface of the ſtones ſhell off in flakes with the weather, which diſſolve and enrich the ſpots all round where they lie. This they continue to do every year till they are almoſt or quite diſſolved, and all lands this manure is laid upon, are much enriched by it. It is a kind of ſtone marle, and greatly improves thoſe eſtates where it is found.

Having thus conſidered the nature and application of the principal ſingle manures, marle, chalk, lime, and limeſtone-gravel; it is unneceſſary to extend our enquiries to other ſingle manures of leſs extenſive uſe; and therefore I ſhall here take notice of only one other kind, which is likewiſe pretty generally uſed, I mean ſoap-boiler's aſhes; a manure recommended by the writers on this ſubject;

ject; but who have not diftinguifhed the different forts of it, though the difference is fo great, that one load of the ftrongeft will go as far as fix or eight of the inferior fort.

To explain this, it is to be obferved, that the foap-boilers in and about London, make ufe of the Spanifh barilla, a kind of pot-afh imported from thence in ferons or large lumps, very clofe, hard and full of falts. This the foap-boilers break and pound very fmall, and fometimes fift it, and being mixed with lime to open it, the falts are wafhed out: but the particles of the barilla are fo hard, that fome of them are not opened by the water, and a confiderable proportion of falts remain ftill in the afhes. When thefe are mixed in a compoft, the harder parts are opened by the fermentation, or by that and the weather, when carried to the land directly. Ten or twelve cart-loads per acre is a good dreffing for cold ftrong land, which is much improved by them: but if laid on warm dry land, a much ſmaller quantity; or to be mixed with ſtrong earth, or other cool manure, otherwiſe they are apt to burn ſuch land.

Kelp made from ſea-weeds is a kind of pot-aſh uſed by ſoap-boilers. It is not ſo hard nor ſo full of ſalts as the barilla; it likewiſe makes a good manure, after they have done with it, but inferior to the former.

Another ſort, very commonly uſed, is wood-aſhes. Theſe being open and ſpungy, their ſalts are readily waſhed out, ſo much, that they make a very weak manure. The farmer ſhould lay on a much larger quantity of theſe than of the two former, or they will diſappoint his expectations.

Another manure, that is for the moſt part uſed ſingly, or without mixture, is the dung of ſheep, commonly laid upon the land in the way of folding. This is an excellent manure for all ſorts of land; and ſo neceſſary where there are extenſive

extenſive farms, conſiſting of large tracts of light dry lands, downs, heaths, and commons; that without the fold, the occupiers of thoſe farms, which frequently lie at a great diſtance from large towns, could not cultivate their arable lands to any advantage for want of manure, in the common methods of cultivation. Theſe light dry ſoils are commonly too poor to ſupport large cattle, but are peculiarly adapted for ſheep-walks. The ſhort dry herbage is moſt agreeable to ſheep, is excellent paſturage for them in ſummer, and while they feed there, they are not ſubject to the rot, and other diſtempers theſe tender animals are liable to, when kept upon low, rich, or wet grounds.

Summer folding has been found ſo advantageous, that ſome farmers are coming into a practice of winter folding their breeding ewes; a method too hazardous to be recommended or approved of. For though ſheep attended by a careful ſhepherd, may be ſafely folded upon

upon loams, and ſtronger land in ſummer, while the ground is dry and warm, it is very different in winter. The land is then generally wet and cold, and confining them in a fold upon ſuch land during the ſnow or cold rains of that rigorous ſeaſon, if it does not immediately kill them, will lay the foundation for the rot, and other dangerous diſeaſes.

All ſorts of cattle thrive beſt that are ſheltered from the inclemencies of weather; and the method they have in Herefordſhire, and ſome other counties, of houſing their ſheep in winter, is greatly preferable to winter folding. The beſt way for this, is to allow them a ſeparate yard, made in the form above recommended, for a farm-yard, and ſheds round it, with racks or cribs to put their hay in, or other food, as turnips, cabbages, cole-ſeed, &c. that they may feed in the dry, and have liberty of going into the yard at pleaſure. The yard ſhould communicate with, or be near to ſeveral ſmall incloſures,

ſures, of ſound dry paſture, to which they ſhould have acceſs in the day-time, and ſhut into their yard at night. Shifting them from one incloſure to another, will contribute to their thriving; for cattle in general love change of paſture, and none do ſo more than ſheep.

The yard ſhould be covered with good mould, and upon that ſome ſtraw or dry fern, &c. by this means all the urine of the ſheep, as well as their dung will be ſaved; and theſe layers of mould and ſtraw may be repeated. A great deal of very valuable manure may be thus obtained, and will more enrich the land it is laid upon, than winter folding it.

The downs, heaths, &c. for ſheep-walks, is of little value, otherwiſe than for providing manure to the other lands of the farm: for it is reckoned by the moſt ſkillful huſbandman, that an acre of ſuch poor land will maintain but one ſheep, and that during the ſummer only: ſome indeed have ſtated two ſheep, and others other three to an acre; but this muſt be for very ſmall ſheep, or better land than common heath or downs. The late eminent huſbandman, Sir Digby Legard, ſpeaking of the Yorkſhire wolds, ſays, "Our farmers ſtock nearly in this proportion, viz. a ſheep for every acre; a flock of five hundred ſheep requires a ſheep-walk of five hundred acres, beſides a winter's ſupply of fodder. Theſe ſheep are ſmall, and when fat, weigh twelve or fourteen pounds per quarter; the fleeces weigh three pounds at a medium, which is ſcarce worth two ſhillings. Of the five thouſand acres (belonging to that gentleman) uninclofed, upon the high wolds, there may probably be about five hundred acres in tillage. The value of the wool may be about five hundred pounds. I ſay nothing of the value of near one thouſand lambs bred every year, nor of the encreaſing value of the weathers and hogs, becauſe the winter ſuſtenance of the flock will be at leaſt an equivalent to the profit on thoſe articles. The winter-keeping of the ſheep will coſt two ſhillings and ſix pence per head; and it is but too true, that the open wolds produce neither hay nor turnips. The ſheep-fold is the only manure we have to depend on. Pigeon's dung is very powerful, and eaſily tranſported, but we cannot get enough of it to enrich much land. I keep about five hundred ſheep, and can fold from May-day to Michaelmas thirty acres twice over."

According to this proportion, the manure raiſed from 8 $\frac{1}{3}$ acres of the wolds, is ſufficient for but one acre of the arable land once folded; or if folding twice over is neceſſary, as it appears to be for this poor land, then one acre requires all the manure raiſed in five months, from 16 $\frac{2}{3}$ acres of the unincloſed wolds.

Again, the winter-keeping of the flock, coſt two ſhillings and ſix pence per head in Yorkſhire, where fodder is at a much lower price than in the more ſouthern coun-

counties. Now, if it is conſidered, that the expence of winter-keeping is repeated every year, till the ſheep are ready to be fattened or ſold, together with the expence of a ſhepherd, caſual charges and loſſes, it will appear, that the profits of the flock, and of the wolds, downs, &c. neceſſary for their keeping, conſiſts principally, if not wholly, in what advantage can be made of the manure. More advantage, it is true, may be made by large ſheep, but theſe cannot be maintained upon ſuch poor land.

Conſidering therefore the hazard of winter-folding, that it may occaſion the loſs of ſome of the flock, and endangering the whole by the rot, and other contageous diſtempers, it is much the ſafeſt way, and the moſt profitable for the farmer, to houſe his ſheep in winter as above-mentioned; by which he may be almoſt certain of preſerving his flock in health, and high condition, and collecting a large quantity of excellent manure.

Besides the single manures, the farmer may have great advantage from composts; which, when they consist of proper materials, and are skillfully mixed, he may safely depend upon. Where a variety of materials can be had, they may be laid as follows; first, clay or strong earth, next soap-ashes, dung, loamy-earth, lime, tanners-bark, green vegetables before they run to seed, earth, soap-ashes, dung, tanners-bark, earth; or as many of these as can be got: also fat-chalk, sea-weeds, sea-sand, and several others; which may be so mixed, as not only to raise a general fermentation throughout the whole compost; but likewise to suit the nature of the land on which it is intended to be laid. The common way is to lay the several materials in layers, one over the other, till a large heap is raised; and it is advised by some authors, and the practice of many farmers is, to make these layers from six inches to a foot in thickness: but this I have found by experience

ence is entirely wrong. For the fermentation raiſed in the compoſt, is not ſtrong enough to penetrate theſe thick layers, eſpecially thoſe of clay or ſtrong earth: for after the reſt have ſufficiently fermented, and the compoſt is turned, theſe layers riſe whole almoſt as when firſt laid, and muſt be broke by hand to mix them with the reſt of the compoſt; whence ariſe two inconveniencies, one, an extraordinary expence of labour, and the other, that twice or thrice turning is ſometimes neceſſary to diſſolve theſe large pieces; and as a new fermentation is excited every time the compoſt is turned, the ſtrength of the manure is greatly waſted, before it is laid upon the land, where it is then incapable of raiſing any conſiderable fermentation, which is one of the principal uſes of manure.

The beſt way therefore of making compoſts, is not in thick layers; but after the ground is marked out for the compoſt, the ſeveral materials, after being well broken, ſhould be laid in heaps round the ſpace marked out for the compoſt heap; and a man placed between each two heaps, to throw the manure ſpreading upon that ſpace; In this manner the compoſt heap will ſoon be raiſed to the intended height, and the ſeveral ſorts of manure being thus well mixed, the whole will ſoon begin to ferment, and will incorporate as fully in two months, as the ſame manures placed in layers in the uſual way, will in four or five. The owner therefore in making ſuch compoſts, ſhould not prepare them too long before they are to be laid upon the land; otherwiſe they will be much waſted, and their beſt parts evaporated.

Compoſts prepared in this manner need not be turned, or at moſt above once. If the fermentation is obſerved to abate too ſoon, make holes with a pole, from the top almoſt to the bottom of the heap, upon which throw urine, or the running of a dunghill, which will fill the holes, force through the whole ſubſtance of the compoſt, and ſoon complete the fermentation.

Such a compoſt, by duly proportioning the ingredients, may be made to ſuit any ſort of land, and is excellent for meadow or paſture grounds. The beſt way to improve theſe, is to cut them about five or ſix inches deep with the five coultered cutting plough, or ſcarificator, which cuts the ſurface in ſlips about three inches aſunder, but does not raiſe or turn them. This cutting of the roots of the graſs, and the manure laid on at the ſame time, ſinking into theſe inciſions made by the coulters, cauſes a ſurpriſing improvement in the quality of the herbage, and alſo makes ſuch graſs-grounds produce three times the quantity they did before. But here it is to be noted, that cutting the ground firſt, and then laying on the manure, makes a greater improvement than manuring firſt and then cutting; and both are ſuperior to manuring and not

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cutting; all which have been proved by accurate experiments. The cutting plough is uſed with great ſucceſs upon clay-grounds, loams, and gravels; but in ſtony grounds, the coulters are apt to be thrown out of their work by the ſtones: and therefore it is not proper to uſe the cutting-plough where ſtones abound.

In ſuch compoſts, where it is intended to uſe a large proportion of earth, that lies at a conſiderable diſtance from the homeſtead, to ſave the double carriage of it to and from the compoſt heap, the dung and other materials may be carried to a headland of the field to be manured, and there mixed into a compoſt.

The beſt ſituation for a compoſt, is upon level ground; or if made upon a deſcent, a trench ſhould be cut on the lower ſide to receive the running of the heap, which is ſome of the beſt part of it, and ſhould from time to time be thrown up again, which will quicken the fermentation.

The richeſt compoſts may be made in the farm-yard, which ſhould he made deepening all round, from the ſides to the middle, in form of a hollow diſh or baſon. When the yard is made up in this form, none of the urine or liquid part of the manure can run off or be waſted. When the dung is carried from the ſtables, cow-houſes, &c. into the farm-yard, they ſhould not be thrown careleſsly in heaps, each ſort by itſelf, but carried in carts or wheel-barrows, and laid regularly, and ſpread all over the yard; upon this ſhould be ſpread a thin layer of earth, mud, the ſcowerings of ditches and ponds, green vegetables before they run to ſeed, and other ſuch materials as are moſt ſuitable to the nature of the land to be manured with them. The racks and cribs, out of which the cattle are foddered, ſhould be frequently moved over the yard, that the offal, ſtraw, and hay may be equally diſperſed, and trod in by the cattle. This method

of

of ſpreading the dung and other materials being continued, the whole will be incorporated with the urine of the cattle, and make an extraordinary rich compoſt. Before it is carried to the land, throw it up in heaps in the yard, and what drains from them will remain in the yard, and none of it will be loſt.

The only inconveniency of this kind of compoſt, is its being filled with the ſeeds of weeds, from the earths mixed with it, and the hay, ſtraw, and dung of the cattle: and is therefore a manure beſt ſuited to graſs-grounds, and to ſuch arable lands as are to carry crops to be hoed, as turnips, cabbages, carrots, potatoes, beans, &c. as theſe weeds will in great meaſure be deſtroyed by good hoeing.

It is common with farmers to uſe ſeveral ſorts of fine or powdered manures ſingly; as ſoot, malt-duſt, rape-duſt, peat and turf-aſhes, ſaw-duſt, lime, kelp and fern-aſhes, pigeon and rabbets dung, &c. but it is ſtill better to mix, as by ſifting or ſcreening, as many of them together as can be conveniently procured. Theſe make excellent hand-dreſſings for graſs-lands, and clover, ſainfoin, and lucern; alſo for wheat in the ſpring, turnips, and other crops; in all which they make a quick improvement. They recover crops that are drooping, and carry on others to perfection: for theſe dreſſings may be repeated ſeveral times in a ſeaſon, at a ſmall expence. The carriage is a trifle, and the trouble is only to ſow it by hand over the crops. This is a very convenient manure, that may be uſed when none other can. The hard manures, kelp and fern-aſhes, and alſo ſhells ſhould be beat ſmall and ſifted; which the owner may have done for about a penny per buſhel. This manure is particularly valuable in another reſpect. It does not make the land foul: for there are no ſeeds of weeds in it. Common ſalt has long been ſuppoſed to be a good manure, but the high duty upon ſalt prevented the farmers

mers making uſe of it. This objection is now removed; for by an act paſſed the eighth of his preſent majeſty, for the encouragement of agriculture, the duty is taken off foul ſalt, which is to be had at the ſalt-works, and is now ſold in London, at four ſhillings per hundred weight, and by the ton at three pounds ten ſhillings. It has not, I believe, been aſcertained what is the proper quantity to be uſed upon land; but by the account of the ſellers of this ſalt in London, the quantity for arable land, is between two and three hundred weight per acre; and for lawns and graſs-walks ſhould be ſown pretty thick, which will enliven the verdure. Sea-ſalt is however of ſo fiery a quality, that it is moſt adviſeable to begin with a moderate quantity, upon every ſort of land, as the quantity may be encreaſed at pleaſure, when the effect of it is known.

Many farmers are of opinion, that the land is apt to tire of one ſort of manure, long and often repeated, but here there is no danger of that. The whole is corrected by the variety in the mixture; and this manure is suitable to all ſorts of land, or may be adapted to any, by varying the mixture.

Before I conclude, I ſhall take notice of ſome new manures propoſed by Dr. Hunter, a gentleman to whom the public is obliged for his attention to improvements in agriculture. In conſequence of his opinion, that plants are chiefly nouriſhed from oily particles, he has propoſed a manure which he calls, the oil compoſt, and directs it to be made in the following manner.

	l.	*s.*	*d.*
"Take north American pot-aſh twelve pounds, coſts —	0	4	0
break the ſalt into ſmall pieces, and put it into a convenient veſſel, with four gallons of water. Let the mixture ſtand forty-eight hours, then add coarſe train oil, fourteen gallons —	0	14	0
£.	0	18	0

In a few days the ſalt will be diſſolved, and the mixture, upon ſtirring, will become nearly uniform.

"Take fourteen buſhels of ſand, or twenty of dry mould; upon theſe pour the above liquid ingredients. Turn this compoſition frequently over, and in ſix months it will be fit for uſe.

"When the liquid ingredients are put to one or two hogſheads of water, a liquid compoſt will be formed, which muſt be uſed with a water-cart.

"I apprehend, that the above quantity will be found ſufficient for an acre; my trials, however, do not give me ſufficient authority to determine upon this point.

"The oil-compoſt is only intended to ſupply the place of rape-duſt, ſoot, woollen-rags, and other expenſive hand-dreſſings. It is in all reſpects inferior to rotten dung: where that can be obtained, every kind of manure muſt give place to it.

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"My experiments teach me, that all kinds of ſoils may be benefited by this manure. The lime-ſtone, gravelly, ſandy, and chalky ſoils ſeem to require it moſt. The rich loams and good clays have nouriſhment within themſelves, and ſtand more in need of the plough than the dunghill."

The doctor likewiſe very juſtly recommends as a rich manure, the refuſe of train-oil, viz. what remains after the oil has been got from the whale-blubber by boiling water, and has hitherto been thrown away. "No manure, ſays he, has hitherto been found of a richer quality than the putrid offal of fiſh. In ſome parts of Cornwall, they manure their lands with pilchards, in a plentiful ſeaſon, and find that no manure equals them in richneſs."

Another very good compoſt recommended by this gentlemen, is made as follows: take a ſufficient quantity of ſaw-duſt; incorporate with it, the blood and offal of a ſlaughter-houſe, putting a layer of one and a layer of the other, till the whole becomes a moiſt and fetid compoſition. Two loads of this compoſt, mixed with three loads of earth, will be ſufficient for an acre of wheat or ſpring corn. Being a kind of top-dreſſing, it ſhould be put on at the time of ſowing, and harrowed in with the grain. If the ſmell of this compoſt ſhould be offenſive, it may be prevented by ſprinking quick-lime between the layers, when the compoſt is made.

All theſe are very good manures, and the only objection to them, is, that they cannot be of general uſe, being to be had only in particular places.

I have ſaid nothing of liquid manures, to be ſpread upon land with a water-cart, as a top-dreſſing; as the powdered manures above-mentioned anſwer the ſame purpoſe with advantage. The liquid manures require a water-cart, and to be drawn by a horſe, which is prejudicial to the land, and the hot quality of them injurious to the tender young plants. The powdered manures do no hurt in this reſpect, if ſown upon the crop in dry weather, and the firſt ſhower of rain waſhes them down to the roots of the plants, the good effect whereof is ſoon perceivable from the flouriſhing ſtate of the crop.

MISCELLANEOUS

DISSERTATIONS

ON

RURAL SUBJECTS.

The principal drill-ploughs hitherto made.—Of Mr. Tull's drill-plough; a general description of it.—Improvement of it by the author.—Of the other principal drill-ploughs, and their defects.—Description of a new and important improvement of Mr. Tull's drill-plough.—The barrel-drill improved, and made a general instrument, to sow all seeds, and at any distance.—Of drilling corn for horse-hoeing, hand-hoeing, and close drilling not to be hoed.—Objections to drilling answered.—Experiments of drilling and hand-hoeing of wheat.—Experiments by Mr. Tull of horse and hand-hoeing of wheat.--His improvements of the hoeing husbandry.—The successful practice of the hoeing husbandry exemplified.—The expences and profits of that husbandry.—Several objections to the hoing culture considered and answered.—Of the alternate husbandry.—The produce and expence of this method compared with the hoeing culture.—The ancient method of alternate cropping and fallowing.—Examples of this culture.—The same compared with the alternate and hoeing culture.

ON DRILL-SOWING.

THE most intelligent husbandmen have long been of opinion, that the common method of sowing corn and other seeds with the hand, or broad cast, was attended with considerable loss in the waste of seed, and often an injury to the crop, by the irregular distribution of it, which in promiscuous sowing is unavoidable, as the seed cannot in that manner be laid at equal distances, nor at any certain depth; but were obliged to continue that practice, not knowing any way of distributing the seed more equally.

It is above a century ago, that some attempts were made, to invent an instrument for planting the seed in a regular manner; and hence the Spanish sembrador, Platt's ſetting-ſticks, and Worlidges' propoſed drill-plough, the laſt of theſe was never brought into practice, and the others were found inadequate in the performance. The firſt inſtrument that really anſwered in practice, was the drill-plough invented by the famous Tull, with which, for a long courſe of years he planted ſainfoin, peaſe, wheat, barley, oats, and turneps.

He adapted his drill to plant wheat in double rows, upon ſmall ridges about four feet eight inches broad, for the purpoſe of horſe-hoeing the intervals between the double-rows; the narrow partitions between the rows on the tops of the ridges, which were ten inches aſunder, he cleanſed from weeds by the hand-hoe, and the rows were hand-weeded. As the ſtaple of all ſorts of land is full of the ſeeds of weeds, this accurate tillage greatly encourages them to grow, and unleſs they are carefully eradicated before they run to ſeed, they multiply, and

greatly

greatly damage the crop; for this reaſon he made his land very clean at firſt, and before he began drilling it, by good fallowing and hoed crops of turneps, and afterwards kept it ſo by hoeing and weeding; till at laſt he ſays, p. 274. "The ſame ſix ſcore acres that was wheat the laſt year, is planted with wheat now, and is all of it as ſtrong, and likely for a good crop, as any of the former years, though there is but about one acre of it dunged. The whole of it is the freeſt from weeds before hoeing that ever was ſeen, and the ſown wheat in the neighbourhood the fulleſt of them."

The ridges to be drilled are made ſtreight, and all of an equal breadth, the tops of the ridges ſhould be made ſmooth by a couple of light harrows faſtened together with a pole, the horſe that draws them walking in the furrows between the ridges. This done, the drill-plough is drawn by a little horſe, along the middle of each ridge, where it opens two channels

nels about two or three inches deep, and ten inches diſtant, into which it delivers the ſeed, and covers it. In this manner it plants ſix or ſeven acres a day, with about three pecks of ſeed per acre, but if planted early upon good land, about two pecks per acre is ſufficient.

Few farmers can believe, that two or three pecks of ſeed-wheat will produce as good a crop per acre, as ſo many buſhels ſown broad-caſt. Or that two rows upon a ridge of four feet eight or nine inches broad will produce as much as the whole ridge covered with plants, not conſidering the number of tillers that ſpring from the drilled, more than from the broad-caſt; the large ſize of their ears and grains, and the great number of grains in the ears; for an encreaſe of ten or twelve buſhels for one ſown broad-caſt is reckoned a very good crop, whereas the drilled often produces thirty, forty, or fifty times as much as the ſeed planted.

To give a general idea of the ſtructure of this inſtrument, Pl. II. fig. 1. is Mr. Tull's drill-plough, with his lateſt improvements, *a*, *b*, *c*, *d*, is a plank, to which the ſhafts, *e*, *f*, are faſtened, and by theſe the horſe draws the whole machine, the rings at the ends of his traces being put upon the hooks at *h*, *h*. The ſpindle *g*, *k*, is drawn by the two double ſtandards fixed into the ends of the plank, and the two wheels and ſpindle turn round together. The ſpindle is in three pieces, grafted together at *m* and *n*, fig. 2. and the middle graft *m*, *n*, has two ſets of notches cut in it, at *o* and *p*, each ſet has ſix notches cut in it round the ſpindle, at equal diſtances, *m*, *n*, fig. 1. is the hopper, made to hold about two pecks of ſeed, half at each end, the hopper being divided in the middle by a board. The hopper is held to the plank, and drawn along with it by the ſtandard *o*, which paſſes through a latch behind the hopper. To the bottom of the hopper the two ſeed-boxes are faſtened.

Theſe

Theſe have large round holes in them to receive the ſpindle, which turning round with the wheels, the notches lay hold of the ſeed, that falls from the hopper into theſe boxes, and bring it down in equal proportions, and it falls from the ſeed-boxes, cloſe to the backs of the two ſhares *gg*, till it reaches the bottom of the channels, in the ground juſt opened for it by the ſhares. The rope *r*, *t*, at the fore-end of the ſhafts, goes over the cart-ſaddle, and has a ſmall chain with a hook at one end of it, *r*, by ſhifting the links of the chain upon a hook faſtened in the ſhaft, at *s*, the ſhafts are raiſed or depreſſed, which regulates the depth of the ſhares in the ground, and makes the ſeed-channels deeper or ſhallower at pleaſure.

The harrow *u w*, is faſtened to the hinder end of the plank, and moveable at *x* and *y*. In the harrow are two tines *t* and *t*, which are ſome inches farther aſſunder than the ſeed-channels. Theſe tines raiſe and turn the mould into the channels,

channels, which covers the ſeed, and finiſh the operation.

This drill-plough performs very well, in land brought into good tilth as I have experienced. There is, however, ſcarce any mechanical invention that does not admit of ſome improvement. Moſt of Mr. Tull's land was a light ſoil, and he made his drill ſuitable to it, very light and eaſily drawn. In ſtronger land, a drill-plough of greater ſtrength is more convenient, and indeed neceſſary; and likewiſe ſome contrivance to manage and guide it ſteadily. To anſwer theſe purpoſes I made ſome alterations, particularly the following.

The long ſhafts are taken away, and in their room are put two ſtrong ones, or ſides-pieces, extending about as far forward as the croſs bar *p p*, and the fore ends elevated as high, (*i. e.* as the croſs bar was before); thoſe have each a hook at the fore-end, upon which are put the rings of two hempen traces, by which the horſe draws the drill. Two handles, like

like thoſe of a common plough are likewiſe fixed to the hinder part of the plank, which ſerve to guide the drill, and to regulate the depth of the ſeed channels: by leaning upon the ends of the handles the ſhares are made to go deeper, and the contrary if the handles are raiſed.

If the land when drilled is dry and fine, the mould will run into the channels and cover the ſeed with little or no harrowing; but two iron tines are commonly uſed in the harrow, and more if the land is rough; for the ſeed, ſhould be all covered, and the harrow is fixed and does not extend ſo far behind the drill, as in Mr. Tull's. His harrow was made moveable, that the tines might riſe over any clods that happened to lie in their way. But by their riſing, ſome part of the ground is miſſed by the harrow, and the ſeed left uncovered. To remedy this, he ſometimes loaded the hinder part of the harrow with a ſtone at *z*; but this is not neceſſary when the harrow is fixed, by which means, and the conveniency of handles to guide the drill, the clods are broke by the tines, or turned aside.

A person who understands the fabric of his drill seed-boxes, can set it by his eye, so as to deliver nearly the quantity of seed he intends to sow upon an acre; but at first it is necessary to adjust it, before he begins drilling.

A statute acre is forty perches in length and four in breadth, five yards and a half to the perch; and the area is one hundred and sixty square perches. Now as there are fourteen of Mr. Tull's ridges in the breadth of an acre, or four perches, and two rows of wheat planted upon each ridge; in the breadth of an acre therefore there are twenty-eight rows, each row forty perches, or two hundred and twenty yards long, which, if planted with six gallons of seed, at $7\frac{1}{2}$ pounds per gallon, is forty-five pounds of seed to all the twenty-eight rows, and one pound and near ten ounces of seed to each row,

three

three pounds four ounces to the double row.

To adjuſt the ſeed-box to ſow this quantity, proceed as follows. Upon ſome level ground ſet up a mark, and place the drill there, having filled the hopper about half full of the wheat to be planted; from the drill-meaſure ſtreight forward eight perches, or forty-four yards, and there ſet up another mark. Then drawing the drill gently forward, from the firſt to the ſecond mark, the notches in the ſpindle will turn out the ſeed as the drill goes on, which is to be received in two ſmall bags or boxes placed under the ſeed-boxes for that purpoſe; and when arrived to the ſecond mark weigh the ſeed thus ſaved; and if each box has delivered $5\frac{1}{5}$, or near five ounces and a quarter, the boxes are ſet right, and need no alteration. For $5\frac{1}{5}$ ounces of ſeed delivered in eight perches length of rows, is nearly forty-five pounds to all the twenty-eight rows; which was the quantity propoſed to to be planted. But if the quantity delivered by one or both the boxes is wrong, open or contract the ſeed-paſſages a little by the regulating ſcrews, and draw the drill from the ſecond to the firſt mark, and weigh again what ſeed is turned out; by a very few trials made in this manner, the ſeed-boxes will be adjuſted to the quantity required.

This may appear troubleſome at firſt, but will become eaſy by a little practice, and the advantage is very conſiderable. I have drilled fields of five or ſix to above twenty acres, with wheat, barley, oats, and peaſe, and adjuſted the drill ſo near, that the ſeed remaining over and above the intended quantity, has not exceeded half a buſhel in drilling twenty acres; and nearly in proportion in drilling ſmaller fields.

The quantity, indeed, would not always have been ſo exact, from the firſt adjuſting of the drill; but there is another circumſtance that contributes to it.

The hopper being divided in the middle with a board, the driller may ſee at all times whether the two ſeed-boxes deliver the ſeed equally, by the equal emptying of the two diviſions of the hopper; and if they do not, they are preſently adjuſted by the regulating or ſetting ſcrews.

Another way of drilling wheat and other kinds of grain, is upon level ground, or broad ridges, in rows about twelve inches diſtant, and hand-hoed. Moſt farmers much prefer this method to horſe-hoing; and in general it produces better crops than the broad-caſt, and the hoeing cleanſes the lands from weeds, and much improves it for the ſucceeding crop. The ſaving of ſeed is a great advantage in this method alſo; for a buſhel of wheat is ſufficient to ſow an acre.

But in this manner of drilling, the drill-plough with only two ſhares is not convenient; requiring too much time to plant any conſiderable extent of land, with

with but two rows each draught, and ſo near together as twelve inches. A drill that ſows four rows at once is the moſt proper, and for this four ſeed-boxes, and the ſame number of ſhares are neceſſary. As this drill ſows only four feet breadth of ground at once, it does not plant ſo much land as that for horſe-hoing, by above an acre a day, but ſhould not be made to plant more than four rows at that diſtance; for it is found inconvenient in practice, to drill a greater breadth of level ground at once than four feet.

In planting wheat to be horſe-hoed, the driller cannot miſtake the diſtance of the rows, the ridges being his guide in that reſpect, and in making the rows ſtraight. But in drilling upon level ground, he muſt have ſome marks to direct him, to make the parting-ſpace between every four rows, a foot wide all the way, the ſame as the ſpaces between the rows made by the drill. The wheels ſerve for this purpoſe; for being made to ſlide upon the ſquare ends of the ſpindle, which has ſeveral holes bored through them; and the wheels, being ſet to the proper diſtance, are confined there by two ſmall iron pins, one at each end, made long enough to paſs through the ſpindle and iron ſtock-bond of the wheel.

To place the wheels for marking, they ſhould be ſet twice as far aſunder as the breadth of the land planted by the drill. Thus in the preſent caſe, the drill plants a breadth of four feet; and therefore the wheels ſhould be ſet at the diſtance of eight feet, each wheel four feet from the middle of the drill; which being drawn along, the wheels make two ſmall impreſſions upon the ſurface of the ground, upon one of which the horſe walks in returning, and drawing the drill directly after him, four more rows are planted, whereof that next the firſt planted will be twelve inches diſtant from it, and thus every turn, the horſe-path is upon the preceding mark of the wheel; and in this

manner

manner the whole field will be drilled in rows ſo nearly equidiſtant, that the parting-ſpaces are ſcarce diſtinguiſhable from the reſt.

If the land is dry, as ſoon as it is made pretty fine by the harrowing, draw a light roller over it to break the ſmall clods, and then the impreſſions made by the marking-wheels will be plainly ſeen; or harrow the field the laſt time acroſs the intended track of the drill, and in this way alſo the wheels will make a viſible impreſſion, ſufficient to guide the horſe; which they will not do, if the drill is drawn in the ſame direction as the laſt harrowing.

The twelve inch ſpaces muſt be hand-hoed: if hoed the firſt time early in the ſpring, twice is generally ſufficient; and ſometimes but once, if hoed late. But the number of hoeings are to be ſuch as to keep the land clean, and there is no loſs, but the contrary, in giving the land a hoeing extraordinary, though there are but few weeds in it. But if the rows are drilled at the diſtance of twenty or twenty-four inches, the intervals may be hoed deep with a hoe made on purpoſe, and drawn by a horſe; and the rows ſhould be earthed up on both ſides at the laſt hoeing. This will likewiſe produce a good crop, and at a leſs expence than hand-hoeing.

There is another method of drilling upon level ground, that does not require any hoeing. The rows are about ſeven inches diſtance, and if the land is very clean, may be eight inches aſunder. When wheat is drilled in this manner, and advances in the ſpring, the rows ſpread and meet, and keep down the weeds. A buſhel of wheat ſows an acre; and the crop is generally ſuperior to that ſown broadcaſt on the ſame land, with the uſual quantity of ſeed.

A drill to ſow in this manner ſhould have five or ſix ſhares, and plant ſo many rows at once: but the ſhares ſhould be in two ranks to ſow the rows ſo cloſe as ſeven inches,

inches, otherwiſe they will drive the mould in heaps, and obſtruct the regular ſowing, unleſs the land is extraordinary fine and clean. This method of planting is called cloſe-drilling, and is proper for wheat, barley, and other grain: I have drilled barley in this manner with ſucceſs. But barley is not fit to be ſown in wide diſtances, that require either to be horſe or hand-hoed; becauſe the hoeing cauſes it to throw out many tillers or branches, at different times throughout the ſummer, and then the barley ripens unequally, the late tillers being green at harveſt when the reſt of the crop is ripe, which leſſens the value of it at market, as it is not fit for malting. This misfortune happens ſometimes to barley ſown broadcaſt, particularly to ſuch as is ſown in a very dry ſeaſon; for then the grains that happen to lie deepeſt in the ground ſpring up without rain; but ſuch as lie near the ſurface do not till rain comes. The firſt by this means gets a-head of the other, ſometimes

P 4 ſeveral

ſeveral weeks, and in that caſe the crop is never all ripe together, but is what the farmers call edge-growed, and when this happens is a great loſs to them. There is beſides another inconveniency in it, the unripe part of the crop, is apt ſome years to ferment in the ſtack or barn, and then the whole is mow-burnt. This is to be underſtood more particularly of barley that has no clover among it, and where it grows rank, and is reaped.

In the latter part of Mr. Tull's practice, he made his drill-boxes of braſs, which is beſt; but boxes made of box or other cloſe hard wood do very well, and are cheaper than braſs. The middle graft of the ſpindle of the drill-plough, in which the notches are cut, ſhould be made of ſound dry heart of oak; the other two parts may be of quartered aſh, or beech.

With the wheat-drills may be planted barley, oats, rye, and ſuch ſized corn; alſo peaſe, vetches, buck-wheat, and ſain-

ſainfoin. But larger boxes are neceſſary to plant beans; and for turnep-ſeed, and other ſuch ſmall ſeeds, the boxes muſt be much ſmaller than thoſe for wheat. So that thoſe who would drill extenſively, ſhould have three different ſorts of drills, proper for planting the different ſized ſeeds above mentioned.

Some who did not underſtand drilling, or were prejudiced againſt it, have objected to the ſlightneſs of Mr. Tull's drill-plough, an objection that may be removed by the above-mentioned alterations, by attending to which, an ingenious workman may ſo ſtrengthen every part, as to make this drill-plough perform its work, with as little danger of being out of order, as ſome of the common inſtruments of huſbandry.

The difficulty of uſing the drill is another objection made to it; and it is admitted, that the owner ſhould underſtand its fabric, ſo as to be able to repair, or put it in order, or direct a workman to

do

it, when any thing is amiſs: but in regard to the management of it in drilling, there is very little difficulty. A prime ſeedſman in the broad-caſt way, will not indeed, be eaſily prevailed with to uſe a drill; but any inferior ſervant employed about a farm, who has ſome ingenuity, and is tractable, will very ſoon learn to uſe it, as it puts him upon an equal footing with the beſt ſeedſman. I have taught ſome ſuch to uſe a drill-plough, that in two days practice have been ſo expert in the management of it, as to go on very well without farther aſſiſtance; and the ſeedſmen, who before ſlighted a drill-plough, ſeeing with what regularity it planted the ſeed, have deſired to learn how to uſe it.

Since the time that Mr. Tull publiſhed his huſbandry and inſtruments, ſeveral ingenious perſons have invented drill-ploughs of different conſtructions from his. One of the firſt was M. de Chateauvieux, firſt ſyndic of Geneva, whereof Mr. Mills,

Mills, in his Husbandry, has given cuts and a description. It is a curious instrument, but complex and expensive, and constructed to sow only three rows at seven inches distance. Mr. Mills has omitted to describe Mr. Tull's drill, supposing it to be more complex than the other; but by mistake, he not being experienced in the practice.

About the same time another sort of drill-plough was invented by M. du Hamel, called a barrel-drill, of which more afterwards. This drill has been introduced into Britain and Ireland, first by Mr. Craik, near Dumfries, in Scotland, a very ingenious practiser of the new husbandry, who has made some material improvements on Mr. du Hamel's drill; and since that, Mr. Wynn Baker has made barrel-drill, whereof the construction was taken, as I am informed, from Mr. Craik.

Mr. Randall, of York, has invented another of a very different construction from

from either of the former, the performance of which I am unacquainted with. And Mr. Baldwin, of Clapham, in Surry, has conſtructed one upon the principles of Mr. du Hamel's, and to plant more rows at once.

Theſe are the principal inſtruments for regular ſowing, that have come to my knowledge, all which are defective in one particular; they are limited to ſow at certain ſtated diſtances, from which they cannot be altered. I had a drill made to ſow ſix rows at once at ſix or ſeven inches diſtance, but that was likewiſe confined to that diſtance, from which it could not be altered; but ſince then, I have contrived a method, by which either Mr. Tull's, or the barrel-drill, may be made to plant from one to ſix rows, and the rows from ſeven inches to four feet diſtance, whereof the following is a deſcription.

Plate II. Fig. 3. *a*, *n*, is a piece of ſound dry oak, perforated lengthways through

Fig. 2.

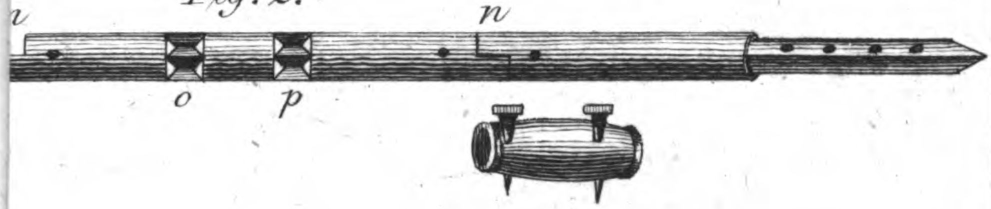


Fig. 3.

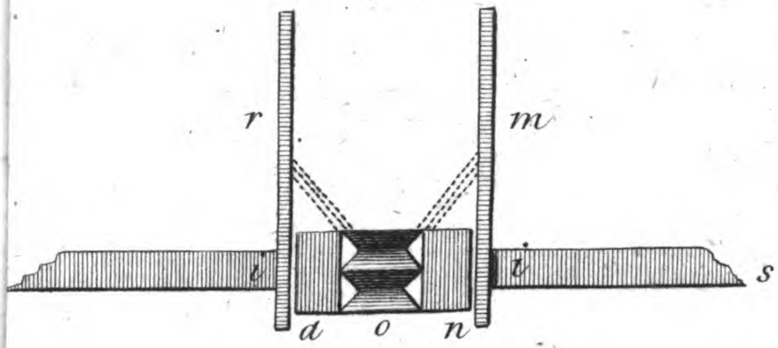


Fig. 4.

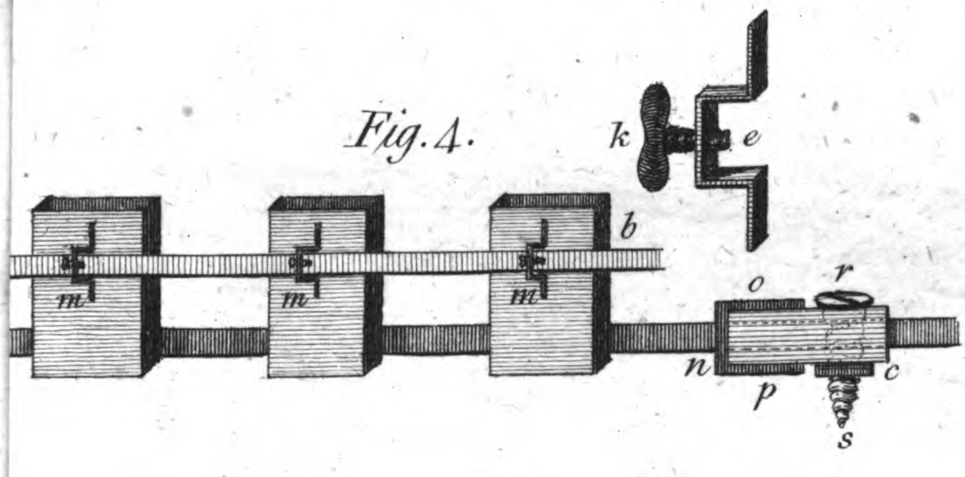


Fig. 5.

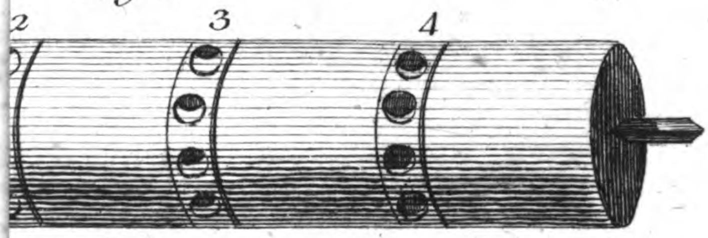
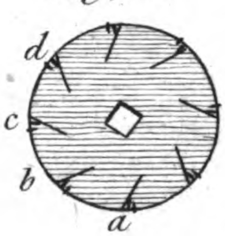


Fig. 6.



J. Lodge sculp.

the middle, by a hole three quarters of an inch ſquare, upon which turn it in a lathe; the parts *a* and *n* to be 1$\frac{5}{8}$ inch diameter, or of a ſize to fit the hole of the drill-box. This round piece of oak repreſents a portion of the middle graft of the ſpindle of Mr. Tull's drill-plough, with ſix notches cut in it at *o*, the ſame form and ſize exactly as in that ſpindle. The ſquare hole made through the middle of the piece, is to receive an iron ſpindle *s s*, $\frac{3}{4}$ of an inch ſquare to fit that hole, ſo as it may be moveable on the ſpindle end-ways, but not to turn round upon it.

A hopper is to be made of elm or walnut-tree ſix inches wide within, one way from *r* to *m* and eight inches the other; the bottom of the hopper to be of inch-board, and the ſides of half-inch. The two ſides *r*, *m*, are to be made deeper than the others, with holes in them for the ſpindle to paſs through at *i*, *i*. The ſeed-box is to be the ſame as the ſeed-boxes of Mr. Tull's

Tull's drill, of braſs or box-wood, and faſtened with ſcrews and nuts to the bottom of the hopper, through which there is a hole made for the ſeed to paſs into the ſeed-box.

The notches or piece of oak, *a, n,* being put into the ſeed-box, and confined from mowing end-ways by the ſides of the hopper at *i, i,* run the iron ſpindle through the ſquare hole of the notches, by turning which round, the ſeed will be brought down by the notches, and delivered into the ſeed-channel, cloſe to the back of the ſhare.* Thus one hopper, and ſeed-box are completed for ſowing one row; and in the ſame manner ſix of them are to be made, all to be put on the iron ſpindle; and as they are made ſeparate and independent one of another, and all to ſlide upon the ſpindle, they may be ſet to the exact diſtance required.

The iron ſpindle is ſix feet long, whereof 4 ½ feet is for the ſeed-boxes and hoppers to ſlide upon, and nine inches at each end

end is to go into two round grafts of wood two inches diameter, and makes the whole length of the ſpindle about ten feet. To ſtrengthen the wooden grafts, and prevent their ſplitting, they have caps of iron as *o*, *n*, *p*, figure 4 and $\frac{3}{4}$ inch ſquare holes at their ends, as at *n*, where the iron ſpindle enters; and the ends of the iron ſpindle are confined as at *r*, *s*, by two iron pins with ſcrews going through them and the wooden grafts, and faſtened with nuts as at *c*. The other ends of the grafts are made ſquare, for the wheels to go upon.

When all the ſix feed-boxes and hoppers are put upon the ſpindle, this drill ſows ſix rows at once ſeven or eight inches diſtant; but to ſow at greater diſtances, one or more of the hoppers are to be taken off, and then it will ſow them wider, but not ſo many rows. Thus ſuppoſe three are taken off, the three remaining will ſow three rows at ſixteen inches aſunder, or at any other diſtance from ſeven to ſixteen inches. Four will ſow at any diſtance, from ſeven inches to twelve; &c. and the ſame drill will ſow double rows upon ridges for horſe-hoeing.

To confine them to the diſtances intended, ſmall iron ſtaples, or of wood like the carrier of a latch, as *m*, *m*, *m*, fig. 4. are fixed to the back of the hoppers, one about the middle of each box, or one above and one below in each; and laths *l*, *l*, being thruſt through theſe ſtaples, the boxes ſlide upon them, and are fixed to the proper diſtances, by ſmall ſcrews with T heads, as *k*, going through one or more of the ſtaples in each box: the ends of the ſcrews made flat and rough as at *e*, and preſſing againſt the laths, will confine the boxes from ſliding. Theſe laths alſo ſtrengthen the iron ſpindle, and prevent its bending.

M. du Hamel's drill above-mentioned, conſiſts of a wooden barrel with three rows of holes round it, ſix or eight holes in each row; a ſpindle paſſes end-ways through

through the middle of the barrel, with a wheel at each end. A ſmall part of the barrel, near the whole length of it, turns upon a hinge, and opens to put in the ſeed, and is ſhut when the barrel is near full. It was made thus at firſt; but ſince Mr. Craik's improvement, the holes in the barrel are big enough to pour the ſeed through into the barrel. As the wheels turn round, they turn the ſpindle and barrel, and the ſeed drops through the holes cloſe to the back of the ſhares in the ſeed-channels made by them: but one great difficulty remained, viz. to regulate the ſize of the holes, ſo as to diſcharge the proper quantity of ſeed.

This Mr. Craik has removed, by making the holes in the barrel large enough for many ſeeds to paſs through at once, and regulating the quantity by the moveable hoops of tin, made to ſurround the barrel, and cover the three rows of holes; and theſe hoops having the ſame number of large holes in them, and at the ſame diſtances as the holes in the barrel, by ſliding the tin hoops round, they cover the holes in the barrel and prevent any ſeed from running out of it; or by bringing the holes in the tin-plates, to thoſe in the barrel, openings are made for the ſeed to paſs, larger or ſmaller as the driller finds neceſſary to diſcharge the intended quantity of ſeed. The quantity to be ſown upon an acre being determined, this drill is to be regulated to ſow that quantity, in the manner above deſcribed for Mr. Tull's drill. This is an excellent improvement; for by this contrivance, any quantity of wheat or other grain may be ſown, from one or two pecks to ſeveral buſhels upon an acre. And what greatly recommends this method ſtill farther, is, that this drill ſows ſeed of all ſizes from the largeſt beans to turnep-ſeed, both incluſive. Carrot-ſeed may likewiſe be drilled with this inſtrument thus improved; the carrot-ſeed being firſt rubbed through a fine wire ſieve

to

to take off the hairy ends of it; for without that preparation the ſeeds ſtick ſo together, that they cannot be ſown very even, by any inſtrument, nor by hand. Mr. Tull's turnep-drill ſows ſuch very light ſeed beſt; becauſe the notches in the ſpindles of his drills lay hold of the ſeed, and bring it down regularly, whether it be heavy or light; and in this reſpect his is ſuperior to all other drills, that have any dependence for their regular ſowing upon the weight of the ſeed.

This is plainly ſeen in the drill now under conſideration. M. du Hamel did not obſerve, that the ſeed run through the holes of the barrel unequally, viz. not ſo faſt when it was full as when it was near empty. This the very accurate Mr. Craik diſcovered in uſing his barrel-drill, and that the ſeed run out floweſt when almoſt full, and gradually faſter as it emptied. He likewiſe invented a method of filling the barrel, whereby it was kept conſtantly ſo equally full, that this inconveniency was remedied; to accomplish which required, however, so much machinery, that the price of his drill is considerably advanced by it. Pl. II. fig. 5. is the barrel-drill; 1, 2, 3, 4, are slips or collars of tin-plate, made to slide in four shallow grooves or channels cut round the barrel; each plate has eight round equi-distant holes in it, about half an inch diameter each, corresponding with round holes in the channels of the barrel, of the same size and number in each channel. By sliding the tin-plates upon the barrel, the holes in them may be brought to stand against those in the barrel, and then, in turning the barrel round, a large quantity of seed would be discharged, much more than is commonly necessary; and by sliding the tin-plate, so as to cover more or less of the holes in the barrel, more or less seed will be discharged: or the holes in the barrel may be wholly covered with the plates, and then no seed will ruu out.

It ſeems at firſt view ſomewhat unaccountable, that the ſeed ſhould run faſter out at the holes of the barrel when near empty, than when it is full; but the reaſon is, that when the barrel is full, the ſeeds at the holes are preſſed by the weight of thoſe above in a greater degree than when there is a ſmaller quantity of ſeed in the barrel, and the preſſure gradually leſſens as the barrel empties. The preſſure cauſes the lowermoſt ſeeds to run cloſer together at the holes, and by that means they obſtruct one another in their paſſage, forming a kind of arch there; the more they are preſſed, the greater is the obſtruction, as it is when the barrel is near full, and the obſtruction is conſequently leſſened as the barrel empties, and the preſſure leſſened.

To regulate therefore the delivery of the ſeed, the preſſure is to be abated, and this may be done by different methods; the following is a cheap and ready way. On the inſide of the barrel fix laths, or thin boards about two inches broad, and the length of the barrel, to which the boards are to be faſtened at one edge, as at *a, b, c, d,* Pl. II. fig. 6. and the other edge at a diſtance from it in a ſloping poſition. The number of theſe boards ſhould be the ſame as the number of holes round the barrel: as ſuppoſe eight holes are made round the barrel to ſow each row, then eight of theſe ſmall boards are neceſſary, to be placed over the holes, in the above mentioned oblique poſition. Every row round the barrel ſhould have the ſame number of holes at equal diſtances in the circumference of it; and they are to be made in ſtreight lines lengthways of the barrel. Being made in this regular manner, each of the thin boards will ſtand over one hole in each circumference.

In drawing the drill forward to ſow the ſeed, the wheels and barrel turn round always the ſame way, as from *a,* to *b, c, d,* fig. 6. and in fitting on the long

long narrow boards over the holes, the edges of them that are fixed to the barrel ſhould be on the riſing ſide of it, as at *a*, *b*, *c*, *d*; by placing them in this manner, they prevent the perpendicular preſſure of the ſeed at the holes, and at the ſame time permit the ſeed to come to the holes, where the preſſure is ſmall, and only lateral.

This contrivance ſerves to regulate the diſcharge of the ſeed, where two or more rows are ſown out of the ſame barrel, and at certain diſtances not to be altered. But a drill to ſow the rows at different diſtances, ſhould have ſhort barrels, one for each row, with ſix or eight holes round the middle of it, to deliver the ſeed. Theſe ſhort barrels have a ſpindle of iron or wood, that paſſes through the middle of each, and upon which they ſlide endways. It is not neceſſary that the middle part of the ſpindle to theſe barrels ſhould be made of iron, as in the drill above mentioned: but for theſe barrels, the whole ſpindle may be made of wood, and grafted in two places as the other. The barrels are confined to the required diſtances by laths, in the manner directed for the boxes in the other drill, and the other parts are nearly the ſame in both.

As this drill-plough ſows all the ſeeds of different ſizes, commonly ſown in the fields, and plants the rows at any required diſtance, it may be accounted an univerſal inſtrument, excelling all the drill-ploughs that I have mentioned above, or have any knowledge of. They all being limited, either with reſpect to the ſize of the ſeed, or the number and diſtance of rows to be planted.

I have already obſerved that the farmers are in general prejudiced againſt the manner of drilling wheat for horſe-hoeing; they are accuſtomed to ſow much ſeed, to ſee the plants come up thick and cover the ground, and cannot believe that two rows only, drilled upon a ridge four

feet

feet eight or nine inches broad, will produce half a crop. They look upon the empty ſpaces between the rows as ſo much ground loſt. They are, however, more reconciled to the manner of drilling in ſingle equi-diſtant rows for hand-hoeing; and ſeveral have in different places, adopted that practice for wheat and other ſorts of corn.

Nor is it the common farmers only who object to wide ſpaces for horſe-hoeing, but others alſo, of larger ideas, have ſuppoſed them unprofitable, and that good crops are not to be expected from them. Among theſe I am ſorry to find one gentleman, the author of the Complete Engliſh Farmer, condemning that method, whoſe cenſure may deter others from giving it a fair trial, eſpecially, as he ſays, he was acquainted with Mr. Tull, and his huſbandry. In order to have a full view of his objections I ſhall recite them.

In

In the preface p. 15, he ſays, " That the deſtruction of weeds, the multiplying of fibres, and the looſening earth about the roots of plants will encreaſe their vigour, are truths that cannot be controverted; but in this country where labour is dear, the expence of performing theſe operations, I am inclined to think, from my own little experience, will exceed the profit. Will any one, who has made the experiment, take upon him to ſay, that in rows only twelve inches apart, the two inches that are planted will produce an equal quantity of grain, after being three times hand-hoed, with the whole fourteen inches planted in the ordinary manner, provided the land is all equally prepared, with an additional exceſs, that will pay for the exceſs of labour.

" In the horſe-hoeing culture, though the expence of labour may be leſs, the waſte of land is out of all proportion greater; for there, only four inches out ſeventy-two are planted, the remaining ſixty fixty-eight are left for the introduction of the hoe-plough. And will any one fay, that in the nature of things, four inches can be made to produce as much grain as feventy-two, provided the whole feventy-two are all in the fame heart before planting? From my own experience I am inclined to conclude they will not."

As to the fuppofed wafte of land in the horfe-hoeing culture, it is admitted that Mr. Tull for fome time, drilled two rows of wheat upon fix feet ridges, which is only four inches planted in feventy-two; but the author fhould have taken notice, that upon fuller experience, he planted two rows upon ridges only four feet eight or nine inches broad, which is four inches in fifty-feven. But not to infift upon this, the author has anfwered his own objection, and acknowledges that four inches drilled in feventy-two may produce as large a crop, as the whole feventy-two fown broad caft: for, p. 213 he informs us, "That Mr. Tull had often

ten upon two rows in ſix feet lands, at the rate of five quarters of wheat on an acre." And this, I ſuppoſe, all farmers will admit is a very good crop, not often obtained upon the whole ſeventy-two inches ſown broad-caſt.

It is from hence evident that the ſpaces between the rows is not a loſs of ſo much land; but being well cultivated by the horſe and hand-hoeing, and kept clean from weeds, are in the nature of a fallow, and the land not only produces a good crop, but it is alſo at the ſame time ſo much enriched by this culture, as to produce another good crop the following ſeaſon without manure, and continues ſo to do every year, ſo long as this culture is continued. Mr. Tull demonſtrates this by his own practice for a courſe of thirteen years, and the ſame has been ſince confirmed by the experience of others, and by ſome for a much longer time.

It ſeems ſurpriſing that any practical huſbandman acquainted with drilling, ſhould

ſhould ſuppoſe that twelve-inch ſpaces will leſſen the crop; or that it is contrary to the nature of things, to obtain as good a crop by the horſe-hoeing as is uſually obtained by the common huſbandry. I ſhall produce ſome inſtances in both caſes, which proves this to be practicable, premiſing one from Mr. Young's account of Mr. Scroope's experiment-field, in Yorkſhire. "In the year 1766, Mr. Scroope, in his experiment-ground, drilled many ſorts of garden plants, in ſingle rows, four feet aſunder, horſe-hoed thrice, beſides hand-hoeings and weedings. Onions, celery, endive, garden beans, coſs lettuce, cauliflowers and artichokes, all proved imcomparably good; and not only ſweeter than his gardener raiſed in the garden, but likewiſe larger and fairer. The ſoil of the experiment-ground is a rich black mold, worth twenty-five ſhillings per acre." It is commonly ſuppoſed, that plants of various kinds extend their roots as far under ground as their tops ſpread above ground; and in ſeveral trials that have been made to diſcover the length of roots, they have been found to ſpread a great deal farther than was expected, though they are too ſmall and tender towards their extremities, to be taken up without breaking them. Roots of wheat have been taken up that were extended three feet from the ſtalks. Whereas in the horſe-hoeing they have only two feet five inches to ſpread from the rows to the middle of the intervals; and in the twelve-inch rows they have but ſix inches to ſpread, till they meet the roots of the adjoining rows. Why therefore ſhould it be thought contrary to the nature of things, that wheat may not by culture extend their roots as far as ſuch ſmall low plants as lettuce and and onions? I ſhall give ſome examples in extenſive practice, and many more might be added, to ſhew, that wheat drilled with wide ſpaces, produce very profitable crops, and at a leſs expence for hand-hoing than the above author has ſtated.

It cannot, however, be truly aſſerted, as by ſome has been done, that the horſe-hoed crops of wheat are in general greater, or even ſo great as the ſown crops, upon the ſame land, or upon land of equal goodneſs, and in the ſame years. The profit of this huſbandry does not altogether conſiſt in the ſuperiority of the crops of this above the common huſbandry; but principally in reducing the expence of cultivation, and ſaving that of manure: whereof none, or very little is neceſſary in the horſe-hoeing huſbandry for corn. This is an important article, and a neceſſary and very expenſive one in the common hnſbandry. It is no ſmall advantage in the hoeing huſbandry, that all the manure uſually beſtowed upon the wheat crop, may be ſaved for the other lands; for the improvement of meadows and graſs-grounds, and for the crops cultivated for cattle, turneps, carrots, cabbages, and cole-ſeed, and for domeſtic uſe, or ſale, as potatoes, hops, madder, and ſeveral others.

With regard to the crops obtained from land drilled in equidiſtant rows, and hand-hoed, though this method of culture is much inferior to horſe-hoeing, as it does not near ſo much improve the land, nor ſo that ſucceſſive wheat crops can be obtained from it; yet it is commonly more profitable than ſowing it with wheat broadcaſt, and the land is, by the hand-hoeing, in much better order for a ſucceeding crop. Neither is the expence of hand-hoeing ſo great as the above author ſeems to think; for once hoeing is frequently ſufficient, and it is very rarely neceſſary to hoe oftener than twice. The hoeing, ſun, and free air between the rows, very much ſtrengthen the plants, cauſe them to throw out many branches, and fill the grain. It is unneceſſary to multiply examples of this, and may be ſufficient to produce one that is unexceptionable, the experiment made by Mr. Cox, near Lymington, in Hampſhire, being a comparative one between wheat ſown

ſown broadcaſt, and drilled in equidiſtant rows twelve inches diſtant; for which the gold medal was adjudged to him by the London Society of Arts, and is related by him as follows:

"Experiments in the culture of wheat, drilled in equally diſtant rows with a drill-plough, and ſown broad-caſt, in November 1767, by Mr. Mathew Cox, of Wallhampton, near Lymington, preſented to the Society of Arts, &c. London.

"The Expence of Tillage, &c. per acre.

One Acre broadcaſt.

Firſt ploughing,	0	7	0
Second ditto,	0	6	0
Third ditto,	0	5	0
Harrow,	0	1	0
Drag,	0	1	0
	1	0	0
Two buſhels of ſeed,	0	15	0
£.	1	15	0

One Acre drilled.

Three ploughings and harrowing,	1	0	0
Drilling, one man and boy, at one ſhilling and four-pence per day,	0	0	4
Hand-hoeing,	0	1	4
	1	1	8
One buſhel of ſeed,	0	7	6
£.	1	9	2

No. of the experiments	When drilled	EXPERIMENTS on Wheat drilled in equidistant rows, 12 inches asunder.	Acres of land	Bushels of seed	Sheaves produced
No. 2	Nov. 6	White wheat on narrow lands, soaked in fresh water 12 hours, in brine 24 hours, and limed; hoed by children the 2d of May, at ½d. per row, which came to 1 s. 4d. was out of the ground two days before the broadcast No. 1.	1	½	151
4	Nov. 6 & 7	White wheat, on narrow lands, prepared as No. 1, &c. hoed by children, 4th of May, ½d. per row, which cost 1 s. per acre. Most of the ears of this wheat and No, 2, were at harvest, 6 and 7 inches long. This piece, and No. 1, 2 and 3, were chalked, about 15 loads per acre,	2	1¾	396
8	Nov. 7	White wheat, on broad lands, brined 12 hours and limed; hoed by my servant, 20th of May,	1½	1½	370
10	Nov. 7	White wheat on broad lands, had no manure, and limed only,	1½	1½	150
13	March 11	Red wheat, on broad lands, 1½ acre, 1½ bushel of smutty seed, brined 48 hours and limed. The weather so wet, the seed could not be covered sufficiently. This wheat was mowed and given to the hogs. This land had borne a crop of carrots, which could not be cleared off, nor the ground prepared till February,			

15 Nov. 20	Red ſmutty wheat, brined 5 hours and limed; hoed by my ſervent the 26th of May. This had borne vetches in 1766, and had no manure,	$\frac{3}{4}$	$\frac{3}{4}$	156
	Total of the drilled crops	$6\frac{3}{4}$	6	1223

" I had as much or more wheat from one buſhel of ſeed ſown in the drill way, as from two buſhel ſown in the common way. One buſhel of lime, which coſt ſeven pence, is ſufficient for twenty buſhels of ſeed. Chalk, &c. nothing charged to either, ſince the expence was the ſame, for the drilled and broadcaſt.

" The drilled wheat produced in general, ſix, ſeven, eight, and ſome twenty-five ſtems from one grain. No. 2 was remarkable for the number of ſtems from each grain, but the quantity of ſeed was too ſmall. I look upon one buſhel of ſeed to be quite ſufficient for one acre drilled, The quantity ſown commonly, in this county, is from two to $2\frac{1}{2}$ buſhels per acre. At the rate which wheat is now ſold, there is a ſaving in the drill method of ſowing, of near the rent of the land; viz. twelve ſhillings and ſix pence per acre.

No. of the experiments.	When drilled	EXPERIMENTS on Wheat fown broadcaft.	Acres of land	Bufhels of feed	Sheaves produced
No. 1	Nov. 5	White wheat, on narrow lands, foaked in frefh water 12 hours, in brine 24 hours and limed. Chalked with about 15 loads per acre. Sowed 2 bufhels of feed per acre. The lands, No 1 to 12, had all three ploughings, and were dragged.	$1\frac{1}{4}$	$2\frac{1}{2}$	190
3	5	White wheat, on narrow lands, prepared as No. 1 and 2, and chalked, at 15 loads per acre,	2	3	140
5	23	White wheat, on narrow lands, dunged and chalked, about 15 loads per acre. The feed brined three hours, and limed: 12 bufhels of foot fown on this piece, the 20th of January,	$\frac{3}{4}$	2	60
6		Red wheat, on broad lands, chalked and dunged as No. 5, and 18 bufhels of foot per acre, in January; the feed brined 3 hours, and limed, $2\frac{1}{2}$ bufhels of feed per acre. Small ears, but very good wheat,	3	$7\frac{1}{2}$	490
7	15	White wheat on broad lands, footed as No. 6. Seed brined 12 hours, and limed,	$1\frac{1}{2}$	$2\frac{1}{2}$	380
9	7	White wheat on broad lands, dreffed with foot as No. 6, the feed limed only,	$1\frac{1}{2}$	2	240

11	7	White wheat, only chalked, brined 12 hours, not limed,	$0\frac{1}{4}$	2	150
12	7	White wheat, had carrots laft crop, cleared off at Michaelmas, had no manure, the feed brined 12 hours and limed,	$\frac{1}{2}$	$\frac{3}{8}$	70
14	20	Red fmutty wheat; not manured; feed brined a few minutes and limed; bore vetches in 1766,	$1\frac{1}{4}$	$2\frac{1}{2}$	324
16	23	Red fmutty wheat, vetches in 1766; had no manure. Seed not brined nor limed. The ears very fmall, but the grains large. Near the hedge they were fmutty, but not half fo much as the feed,	$1\frac{1}{2}$	3	261
		Total of crops broadcaft,	14	$27\frac{3}{8}$	2305

"The field in which thefe experiments were made, is called Wimble Field, fituated on Wallhampton-Hill, on the eaft fide of Lymington river. It contains twenty-three acres within the fence. It is a fhallow mould on a gravel. The whole field is nearly alike, excepting that from No. 12 to 16 the foil is a little lighter and deeper.

"The number of ſheaves produced by the drill culture were not ſo many in ſome of the experiments as by the broadcaſt, but they all weighed more, and produced more grain. The ears alſo were conſiderably longer; which I attribute to the hoeing, and the length of time the ſeed was ſteeped in brine. November 12, 1767.

"November 19, N. B. Since I wrote the above, I have threſhed a quantity of both the red and white wheat, and find, that twelve ſheaves of the red wheat, cultivated in broadcaſt, yield one buſhel of grain; whereas from ten ſheaves of the white wheat, cultivated in drills and broadcaſt, the ſame quantity may be obtained. I have threſhed five-hundred ſheaves of the produce of each of the methods of culture; the ſheaves were as equal in ſize as poſſible, and weighed about twenty pounds each. The ears I have ſent to the ſociety were not picked, but the general ſize of each experiment."

LETTERS to Dr. TEMPLEMAN, Secretary to the Society.

"SIR, Wallhampton, May, 2, 1768,

IN anſwer to yours, the ſeed was harrowed in, except the lands ſown with the drill-plough, which were harrowed before they were ſown. We ſowed about three acres per day with the drill-plough, which finiſhed. I think three buſhels of lime were all that were uſed for the ſeed of this field. The firſt ploughing we charge ſix ſhillings per acre; the ſecond five ſhillings, and the third four ſhillings. I have ſown ſome wheat with the drill-plough laſt Michaelmas, have now ſixteen ſtems from many of the ſingle grains, and think it has not done tillering.

"SIR, Wallhampton, May 14, 1768.

I received your favour this morning. The land for the drilled wheat was prepared exactly the ſame as the land ſown in the common way; only the land for the drilled-wheat was harrowed before the drilled-plough went on. My drill-plough ſows four rows, and harrows it. I had on an average twenty-three Wincheſter buſhels per acre drilled."

REMARKS on theſe EXPERIMENTS.

The $6\frac{1}{4}$ acres drilled produced 1223 ſheaves, whereof 1167 were from the 6 acres of white wheat, 10 ſheaves of which yielded a buſhel of grain, in all $116\frac{3}{4}$ buſhels, and near $19\frac{1}{2}$ buſhels per acre.

And the $\frac{3}{4}$ acre of red wheat produced 156 ſheaves, at a buſhel per 12 ſheaves, is $20\frac{3}{4}$ buſhels per acre. The average, therefore, of the drilled crop is nearly 20 buſhels per acre, by computation from the ſheaves; but Mr. Cox ſays he found the real produce, on an average, was 23 buſhels per acre.

The

The 14 acres broadcaſt produced 2305 ſheaves, of which the $8\frac{1}{4}$ acres of white wheat yielded 1230 ſheaves, at 10 ſheaves per buſhel, is $122\frac{1}{4}$ buſhels, and $14\frac{3}{4}$ buſhels per acre.

And the $5\frac{3}{4}$ acres of red wheat produced 1075 ſheaves, at 12 ſheaves per buſhel, is $89\frac{1}{2}$ buſhels, and $15\frac{1}{2}$ buſhels per acre, conſequently the average of the broadcaſt is 15 buſhels per acre, computed from the ſheaves.

But as the real produce of the drilled exceeded the computed, probably the difference in the broadcaſt might be nearly in the ſame proportion, viz. as 23 to 20; and in that caſe the real produce of the broadcaſt was $17\frac{1}{4}$ buſhels per acre; which is $5\frac{3}{4}$ buſhels per acre more from the drilled than the broadcaſt, at 7 ſhillings and 6 pence per buſhel is, £. 2 3 $1\frac{1}{2}$

Alſo

Brought over	2	3	1½
Alſo a buſhel in ſeed ſaved per acre,	0	7	6
	2	10	7½
But in tillage, the drill coſt more than the broadcaſt per acre,	0	1	8
The drilled moſt profitable per acre,	2	8	11

The rent is twelve ſhillings and ſix pence per acre; ſo that the profit of the drilled was more than the broadcaſt, very near four rents of the land: an ample encouragement to farmers to cultivate their wheat in this manner.

The hoeing being performed by children, it was probably done but ſuperficially; and was only but once hoed. Had the land been well and deep hoed early in the ſeaſon, and the hoeing repeated, the drilled crop would have been ſtill more plentiful, and the land much improved for the ſucceeding crop. To ſhew this more plainly, it may be ſufficient to refer to Mr. Tull's own experience, who firſt introduced into the fields the hand-

hoeing

hoing of wheat and other crops. The account he gives of his hand-hoed wheat, is as follows, p. 50.

" About the year 1701, ſays he, when I had contrived my drill for planting ſaint-foin, I made uſe of it alſo for wheat, drilling many rows at once, which made the work much more compendious, and performed it much better than hands could do; making the channels of a foot diſtance. Drilling in the ſeed, and covering it, did not in all amount to more than ſix pence per acre expence, which was above ten times overpaid by the ſeed that was ſaved: for one buſhel to an acre was the quantity drilled. There remained then no need of hand work, but for the hoeing; and this did coſt from half a crown to four ſhillings per acre. This way turned to a very good account, and in conſiderable quantities. It has brought as good a crop of wheat on barley ſtubble, as that ſown the common way on ſummer fallow; and when that ſown the old way, on on the ſame field on barley ſtubble, entirely failed, though there was no other difference but the drilling and hoeing. It was alſo ſuch an improvement to the land, that when one part of a ſtrong whitiſh ground, all of equal goodneſs, and equally fallowed and tilled, was dunged and ſown in the common manner; and the other part was drilled and hand hoed without dung; the hoed part was not only the beſt crop, but the whole piece being fallowed the next year, and ſown all alike by a tenant, the hoed part produced ſo much a better crop of wheat than the dunged part, that a ſtranger would have believed by looking on it, that, that part had been dunged which was not, and that part not to have been dunged which really was."

And in 1738 he writes as follows, "I was deſired to take an exact account of the product of a ſingle land of hand-hoed wheat, and of an acre in the middle of a field

field of twenty-five acres of horſe-hoed wheat, in order to know the different quantities produced by them.

The acre of horſed-hoed wheat yielded twenty-nine buſhels and ſix gallons (nine gallons to the buſhel) but there was very great waſte made by the reapers to whoſe lot this acre fell. This waſte was greater than any I had ever ſeen; ſo that I believe, if it had been as well reaped as moſt of the reſt of my wheat was, there would have been thirty-two buſhels received from this acre.

The land of hand-hoed wheat was in a common field, and planted upon the level, with the ſamed drill that planted the other, whereby there was a ſpace of ten inches between two rows, and a ſpace of eighteen inches between thoſe and the next row; ſo that each row had fourteen inches of ſurface for the roots to ſpread in. It was hand-hoed very well. The land hath not been dunged in any manner ſince the year 1719. This crop was

was reaped very low, and thrafhed out immediately. It produced eleven bufhels and a half; the meafure of the land being fifty-two perches, the product is at the rate of thirty-fix bufhels and fix gallons to an acre. It is fituated next to the ditch of a meadow, and is all the land I have in the common field. The lands adjoining to it, of the fame goodnefs, were judged by all gentlemen and farmers who viewed them, not to have above half the wheat on them that this had, perch for perch; and yet there was no difference in the management, except this being regularly planted and hand-hoed, without dung; and the other fown at random, and dunged (as they always are, once in three years) the fallowing and ploughing of both were the fame. Mine was faid by feveral farmers of the place, to be the beft land of wheat in the parifh.

"This indeed ought to be allowed, that mine being moftly white cone wheat, and the adjoining lands of clean lammas, might make fome part of the difference: but there being fome of the fame fort of lammas amongft this cone, it was obferved to be as high as the cone, and the ears of it to be of double the goodnefs of thofe in the contiguous fown lands.

"The difference of the appearance of the hand-hoed and of the horfe-hoed, whilft they were ftanding, was fo great as to deceive many who faw them, and to induce fome to imagine, that the product of the former would be double to that of the latter; though it was really little more than an eighth part greater.

"The horfe-hoed fhews the whole interval empty, until the grain is almoft full, which is a great advantage to the crop: becaufe unlefs the air did freely enter therein, to ftrengthen the lower parts of the ftalks, they would not be able to fupport fuch prodigious ears (fome con-

containing one hundred and twelve large grains apiece) from falling on the ground."

And p. 274, he ſays, "My ſingle land of fifty-two perches in the common field, mentioned in my *Addenda*, brought the laſt harveſt a crop of barley (in the opinion of all who viewed it) double to the land of the ſame goodneſs contiguous to it, at the end and ſide of it. This ſhews that the benefit of the pulveration of one good hand-hoeing, performed half a year after planting the wheat, together with the leſs exhauſtion of half the ſeed, and no weeds, vaſtly exceeded the uſe of the dunging for the wheat, on the contiguous land, there being no other difference."

Theſe examples ſufficiently prove the advantage of drilling wheat in rows, twelve inches and more diſtant, for hand-hoeing; and that it is a much more profitable method than ſowing broad-caſt. The objection to the wide ſpaces between the rows is of no weight. The plants

plants recive their nouriſhment by their roots; the more numerous they are, and the more competent room they have to ſpread, the greater ſhare of nouriſhment the plants receive from them. In one caſe the hand-hoeing opens the ſoil ſo much, that they extend through the twelve and fourteen inch ſpaces; but in the other the ſoil is ſo much more opened by horſe-hoeing, that two rows only, upon a ridge fifty-ſeven inches broad, produced near four quarters of wheat per acre, nine gallon meaſure. As the partition between the double row on the top of the ridge, was only ten inches wide, the interval between the double rows, was forty-ſeven inches, or near four feet wide, through which, notwithſtanding, the wheat roots extended, as appears by the goodneſs of the crop. The diſtance, therefore, between the rows of twelve or fourteen inches is no valid objection to this manner of drilling wheat to be hand-hoed.

On the contrary it has been found, that drilling the rows two feet diſtant, produces better crops than at half that diſtance, provided the mould between ſuch wide rows is well hoed; for which purpoſe a ſmall plough is much preferable to the hand-hoe, and the tillage cheaper.

In cloſe drilling, the rows are planted about ſeven or eight inches aſunder. The crop is not ſo good as the twelve inch rows; but is equal to, and often better than the broad-caſt, and half the ſeed is ſaved; for in cloſe drilling about one buſhel of ſeed is ſufficient. Many farmers approve of this way more than the twelve inch rows; becauſe the ground is more covered with plants, and that it is not neceſſary to hoe them. Where a conſiderable extent of land is drilled in this manner, the ſaving of ſeed is an object deſerving the farmers notice. The following inſtance from Mr. Craik, near Dumfries, in Scotland, is ſufficient to ſhew

ſhew this: writing of his drill-plough he ſays, "Thoſe who do not incline to dip into the horſe-hoeing huſbandry, may uſe this drill to ſow their fields in cloſe drills, which will be a ſaving of more than one half the ſeed. I was lately with a gentleman in Annandale, who told me he ſold for fifteen pound this ſpring, the oats he ſaved in ſeed, by ſowing his fields with my drill-plough, and yet I have not ſeen a finer crop this ſeaſon, though neither horſe or hand-hoed."

I have taken notice above, that the laſt mentioned author has objected to the drilling or horſe-hoeing of wheat, on account of the wide ſpaces between the rows—That Mr. Tull laid his land into ſix feet ridges, and drilled two rows upon each ridge; and therefore that only four inches in ſeventy-two was planted, the remaining ſixty-eight inches having no crop upon it, but was left unplanted, in order to introduce the hoe-plough.—That he directs ſix, or even eight hoeings to be given to a crop—And that at the ſummer hoeings, the plough ſhould not come very near to the rows of wheat.

" The third hoeing (in ſummer) ſays he, p. 182, was performed in a particular manner, as well as the firſt and ſecond: for as the fibres of the roots had now acquired conſiderable ſtrength, and were known to have extended a conſiderable way into the intervals, Mr. Tull judged it improper to tear any conſiderable number of them off at once with the plough, and therefore his inſtructions to his ploughmen were, to keep at a greater diſtance from the rows, and to depreſs his left hand, that by the ſlant poſition of the plough, the ſhare might paſs over the lowermoſt extended fibres without hurting them, and at the ſame time by looſening the earth above and beyond them, leſſen the impediment that might have retarded their farther extenſion."

" After this hoeing the plants were ſuffered to remain a ſhorter or longer time,

time, according to the appearance of the crop, or the increaſe of the weeds. If the plants appeared ſickly, they were immediately reſtored to health by the application of the hoe; or, if the weeds had gained ground, they were removed by the ſame means.

"The laſt hoeing, however, which was ſometimes the ſixth, or even the eighth, was always performed as ſoon after the wheat was out of bloſſom, as the weather would permit. This hoeing Mr. Tull eſteemed one of the moſt eſſential.

"Thoſe who would be ſatisfied of every little nicety, muſt conſult Mr. Tull's book of horſe-hoeing huſbandry, which in truth deſerves to be more generally read, than, I believe, it has hitherto been."

Here it is to be obſerved, that the horſe-hoeing was a new method of huſbandry, never practiſed in the culture of wheat, till it was introduced by Mr. Tull: and it may be ſuppoſed, which indeed is the fact, that his first essays were imperfect, or capable of improvement; and accordingly we find, that upon further experience, he made several important alterations and improvements upon his first practice. How it has happened, that this gentleman, who describes this husbandry, should take notice of Mr. Tull's first practice only, and wholly omit these improvements, must be attributed to his not having read the latter parts of Mr. Tull's work: for his book of horse-hoeing husbandry, properly so called, contains his first practice; but he published several additional parts at different times, during a course of six years; which it is necessary for those who would make trial of this husbandry, and perform it in the best manner, to be acquainted with.

That he altered the breadth of his ridges, from six feet to four feet eight or nine inches, appears from the following passage in his *addenda* to the book of horse-hoeing; where he says he made fourteen

fourteen ridges in the breadth of an acre, or four perches. P. 262.

"I now chuſe, ſays he, to have fourteen ridges on an acre, and one only partition of ten inches on each of them. This I find anſwers all the ends I propoſe. If the partitions are narrow, there is not ſufficient room for the hand-hoe to do its work effectually; if wider, too much earth will loſe the benefit of the horſe-hoe.—By all theſe three methods, (viz. double rows planted upon level ground; treble rows upon ſix feet ridges; and double rows upon narrow ridges, of fourteen ridges on the breadth of an acre) I have had very good crops; but this I now deſcribe is the lateſt, and, as it ought to be, the beſt; I publiſh it as ſuch, without partiality to my own (former) opinions."

And, with regard to the manner and number of the horſe-hoeings, he directs in his *Concluſion*, or laſt part of his work, as the reſult of all his experience, p. 272. "At the ſecond (or ſpring) hoeing, ſays he, the plough goes in the furrow of the firſt; making it deeper and nearer to the wheat. The third hoeing fills up this furrow; and then at the fourth hoeing, the plough goes in the ſame place as the ſecond, turning the mould into the interval. It is remarkable, that though the furrows of the ſecond and fourth hoeings be deep and near to the rows, ſeeming to deprive the wheat of the mould which ſhould nouriſh it, whereby one would imagine, that theſe furrows lying long open ſhould weaken or ſtarve it, but it is juſt the contrary; for it grows the more vigorous. And it is the obſervation of my ploughmen, that they cannot at thoſe hoeings go too near to the rows, unleſs the plough ſhould tear out the plants.

"If I may preſume to aſſign the cauſe of this ſurpriſing effect, it is, in my opinion, the following, viz. This open furrow has a double ſurface of earth, which by the nitre of the contiguous atmo-

ſphere,

ſphere, is pulveriſed to a great degree of minuteneſs near the row. The roots that the plough cuts off on the perpendicular ſide of the furrow, ſend out new fibres to receive the pabulum from this new made paſture: and alſo part of this ſuperfine powder is continually falling down into the bottom of the furrow, and there gives a very quick growth to thoſe roots that are next it, and a quick paſſage through it into the earth of the interval, where they take likewiſe the benefit of the other ſide of this pulverized furrow. When it is ſaid that air kills roots, it muſt not be underſtood that it kills a plant, unleſs all, or almoſt all its root is expoſed to it, as it is not in this caſe. Some think that there are roots that run horizontally, below the plough into the interval: but of this I am not convinced.

"It is not often that we hoe above four times; and then the furrow is turned towards the row at the third time only.

"There

"There being no danger from theſe furrows lying long open, we are not confined to any preciſe diſtance between the times of hoeing; for which we need only regard the weather, the weeds, and our own convenience of opportunity and leiſure.—Whether theſe furrows lying long open next the rows in very hot dry climates may be prejudicial, cannot be known but by trials.—I prefer planting the rows on the precedent intervals.

"The number of ridges being encreaſed, as their breadth is diminiſhed, occaſions ſomewhat the more plough work; we likewiſe uſe more handwork than formerly: but the profit of this encreaſed labour, is more than double to the expence of it.

"It is better to make fifteen ridges on an acre, than to leave any earth unmoved by the hoe-plough in the middle of the intervals. But when ploughmen by practice underſtand well to uſe the hoe-plough, they will plough the intervals clean,

clean, though the ridges are only fourteen on an acre."

It is evident from theſe paſſages, that Mr. Tull's improved method, was to drill his wheat, not upon ſix feet ridges, but upon narrower ones of four feet eight or nine inches.—That he commonly hoed his wheat only four times. And that he horſe-hoed it cloſe to the rows every time in ſummer. Alſo that is not neceſſary to be critically exact, with reſpect to the times of hoeing. And upon the whole it appears that horſe-hoeing of wheat, is not ſo nice and difficult as many ſeem to apprehend. The moſt extraordinary circumſtance is, that the wheat continues to thrive after the earth is ploughed away from the rows towards harveſt, when the plants are at their full growth, and the grain filling; which I am certain is a fact, from inſpection of ſeveral crops ſo done; though I have not my ſelf practiſed that method; becauſe it requires more time and ploughing to form the new ridges for the next crop, than is neceſſary, when all the earth is ploughed up to the rows at the laſt hoeing; provided the next crop is to be drilled upon the former intervals, which is the moſt expeditious, and, in my opinion, is in general the beſt way.

And that the reader, who would practiſe this huſbandry, may be further ſatisfied, that the method here directed by Mr. Tull, has ſucceeded with others ſince, I ſhall give another nearly ſimilar to it, practiſed by Mr. Craik, as deſcribed by himſelf; after reciting what he ſays of the nature of his land.

" My ſoil, ſays this gentleman, is ſtiff and very moiſt; that is, the bottom below the ſtaple is a hard and almoſt impenetrable till, impervious to water, which of conſequence keeps the top poachy: and therefore am obliged to drain every field with covered drains, filled with ſtone. Add to this, that our climate is extremely watery: ſo that both ſoil and climate are againſt me, eſpecially in the new huſbandry.

"About ſeven years ago, I began to drill wheat in double rows, on ridges five feet two inches broad, but have now reduced them to four feet ten inches, on the laſt taken in fields, which ſize I find anſwers every purpoſe beſt for double rows. I drill a little ſhort of a Wincheſter buſhel to the Scots ſtatute acre (viz. one acre and a quarter Engliſh); my return, upon the average, is about twenty-five of ſaid buſhels, ſince I firſt began: and the total expence, harveſt-home, is about a guinea, ſeed included. But the return would conſiderably exceed this, were it not for ſome parts in every field, that have every year quite failed; in ſome occaſioned by a vein of ſandy gravelly ſoil, that runs acroſs two of my fields; and in all the others, from the old ridges being very high raiſed by the former farmers, and at the ſame time very broad and crooked; which obliged me to level the

whole:

whole: the confequnce of which is, that the tops of the old ridges continue barren for feveral years, to my great lofs. I was for fome time in hopes that frequent cultivation and expofure to the air, would in time remedy this defect, but finding little alteration in thofe parts, I am now applying proper dreffings, fuited to the different foils, which I have already found will anfwer the purpofe, and make a very fenfible difference in my profits.

"When the crop is off, the ridges are ploughed up and formed anew; then fmoothed by the drill harrows, and drilled with the drill-plough, which delivers the quantity of feed intended, and exactly at any propofed depth, covers and rolls it at the fame time, and is fo fimple, that any perfon may conduct it at firft trial. When the wheat has got three or four leaves, I hoe from the rows, agreeable to Tull. In the fpring, I always deepen the fame furrows made before winter; after which it lies till the wheat begins to fpindle,

when

when I horſe-hoe back the earth, ſo as to earth up the plants two or three inches, to ſtrengthen and ſecure them. In this operation, a ſlip of earth remains untouched, in the middle of what was ploughed firſt from the rows; and as a new ſurface is expoſed by the laſt hoeing, I leave that ſlip untouched for ſome time, to receive the advantage of expoſure, and till the weeds come, when I plough up this ſlip with the double mould-board plough, which covers the weeds and leaves a wide, deep, and clean trench. If the wheat ſtands fair, ſo as to admit the horſe-hoe, which with me is ſeldom the caſe, I hoe a ſmall furrow back from the rows, and return it with the double mould-board plough; but do not think this neceſſary, if the former operations are properly executed.

" Though my ſoil is ſtiff and heavy, I only uſe two horſes to the ſingle hoe, and three to the double mould-board hoe. The ſingle hoe hoes two and an half Scots acres per day, and the double mould-board five: the firſt having a full bout to each ridge, the other only a half bout. I have tried to hoe with oxen, but found they did not anſwer in my wet ſoil, and now only uſe horſes, as they poach the land leſs.

"I have now the ſeventh crop of drilled wheat, growing on my firſt acre, which I choſe as near the average of my ſoil as I could, and it at preſent promiſes to be the beſt. This acre conſiſts of twenty-two ridges, nine of which were three years ago ſtrongly dreſſed with dung, that ſide being lighter land than the other, and generally failed. Since dreſſing, that part has proved better, but ſtill inferior to the undunged ſide. This acre, as well as all my fields, was dreſſed at firſt with ſhells, and bore four broadcaſt crops immediately preceding the drilled crops. I have only this year thirty Scots acres of drilled wheat; the wet ſeed-time laſt year having prevented my drilling a ten acre field,

field, now in turneps and potatoes: for I dare not touch my ſoil with the plough when wet.

"The field with the ſixth crop of drilled wheat, and which had five broadcaſt crops previous to theſe, hath at preſent as full a crop as can ſtand upon it, except where the ſandy vein comes in. The field, with the fifth crop, is inferior to it, though equally good ſoil. In general, where the ſoil was originally tolerable, and, excluſive of the particular accidents I have mentioned, I cannot perceive hitherto any decline in the crops, even thoſe that have not received any dreſſing with dung; but how long this will go on, time only can determine.

"I have uſed the white lammas wheat, the Kentiſh red, the Zealand from Holland, the white and gray cone, and this year a ſmall quantity of Smyrna wheat, *ſpica multiplici*; yet I find none of them can reſiſt the violent ſtorms of wind and rain of our climate. Both the cones ſtand the beſt; but our millers have not art enough to grind them; on which account our bakers are ſhy to buy them. I have moſtly ſown the gray cone. A great part of my laſt year's crop went to the Iſle of Man, to Ramſey, and was ſo large a grain, that our bakers objected to it on that account.

"My crop this year conſiſts of the gray cone, the red Kentiſh, and the white lammas, ſome of each in the ſame field, on purpoſe to ſee which ſtood beſt; and now find the red Kentiſh has ſuffered moſt, and the white lammas, of a kind I had from London, ſtands equally well with the gray cone, which has determined me to ſow it moſtly, for the enſuing crop.

"This year's crop had more than uſual a luxuriant appearance, both the drilled and broadcaſt; but when it came to be cut down, I found it almoſt quite ruined by the blight, occaſioned, I ſuppoſe, by the uncommonly cold and wet months of May and June, together with the cold

and

and moiſt quality of my ſoil. The broad-caſt appears rather to have ſuffered more than the horſe hoed, though all of the gray cone, are a hardy ſort. I am afraid this will be but too general, as I am informed by ſome of my correſpondents of the London Society, that they have obſerved, that even the graſſes have not perfected their ſeeds this ſeaſon.

"My drilled wheat is generally, by the time it gets into bloſſom, ſo laid over, but not broken, that I can neither horſe-hoe, hand-hoe, or hand-weed; ſo that a ſecond crop of weeds never fail to ſpring up, time enough to ripen the ſeed, before the crop is cut; and this, with me, is the great and invincible objection to a ſucceſſion of wheat crops in this way; at leaſt in my ſoil, and this climate. What I propoſe to remedy this is, to take a crop of horſe-hoed turneps, next a horſe-hoed crop of beans, and next two or three crops of horſe-hoed wheat, and then return to the turneps. In this way I am ſure to extripate the weeds during the turnep and bean crops; and have reaſon to expect my wheat ſhould be a full crop, after theſe meliorating ones.

"Were it not for the parts that fail in my fields, my horſe-hoed crops would exceed four quarters. Laſt year on half an acre Scots, I had twenty-two Winchesters; but this was all equally good.

"I always horſe-hoe from the rows at one bout, half a bout to each ſide, and could return this bout with the double mould-board, at half a bout; which was for ſome time my practice; but now find it more profitable, firſt to return the bout by another bout of the ſingle hoe; which expoſes a large new ſurface: and then, when the weeds are up, clean up with the double mould-board. But as, at the ſecond hoeing from the rows, which is after the grain has got into ear, I only take two ſmall furrows, viz. one from each ſide, theſe I return at once, with the double mould-board."

This

This gentleman's account of the horſe-hoeing of wheat, is very clear and conciſe, and merits the particular attention of thoſe who are inclined to practice this huſbandry; the ſucceſs whereof is very apparent here, notwithſtanding the very unfavourable ſoil and climate.

"The objection made by the forementioned author, to the wide ſpaces between the rows, and ſuppoſing them to be ſo much waſte ground, is here demonſtrated to be groundleſs. Mr. Craik's ridges are four feet ten inches broad, and the partition between the double row on the top of the ridge eleven inches: the horſe-hoed interval, therefore, is near four feet broad, which, though no plants grow upon them, yet furniſh the roots of the double row with ſo much nouriſhment, that the crop is as good as the broad-caſt, that covers all the ground with plants.

Likewiſe, inſtead of ſix or eight hoeings, as mentioned by the ſaid author, Mr.

Craik gives only four hoeings, the effect whereof is very great.

The profit likewife from this culture is remarkable. The total expence of cultivation, harveft-home, and feed included, being about a guinea per acre, if the expence and rent amounts to forty fhillings per acre, the crop of four quarters per acre, which he fays they exceed, exclufive of the tops of the old ridges, and fandy vein, being reckoned only at eight pounds, there remains fix pounds per acre. A profit greatly exceeding that of common wheat crops.

Sir Digby Legard fays, the farmers profit on the Yorkfhire wolds, from their wheat and barley crops, is only about four fhillings per acre. And the Complete Englifh Farmer reckons that the occupier of a farm of two hundred pounds a year rent, confifting of five hundred acres, viz. about three hundred acres arable, and the reft meadow, pafture, &c. ought to have a capital of fifteen hundred pounds.

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"The whole ſum which ſuch a beginner, ſays he, p. 62, ſhould be poſſeſſed of, ſhould not be leſs than fifteen hundred pounds; for neither will the farm be over-ſtocked, nor the ſtock over-rated.—He muſt not flatter himſelf, that leſs than fifteen hundred will ſuffice. Let him remember, that if he once gets the name of a bad paymaſter among his neighbours, it will require many years cloſe application to buſineſs to redeem his credit; and that up-hill work, as the phraſe is, long continued, will tire the beſt horſe in the farmer's team."

The profit arriſing from this farm, ſo ſtocked, he eſtimates at about fifty pounds a year, being, he ſays, what the farmer can expect to ſave at the year's end, over and above maintaining his own private family. "Fifty pounds a year, ſays he, p. 204, laid by in clear profit, is nearly as much as a farmer can annually accompliſh, who rents two hundred a year."

The ſum he ſuppoſes neceſſary to begin with, is much beyond what farmers in general can attain to, who rent farms of two hundred a year. And if ſo much was neceſſary, and the profit ſo ſmall, few perſons, I believe, could be found capable of renting them; and very few would breed up their ſons to agriculture.

Hence, however, the advantage of horſe-hoeing culture is very apparent: for, according to Mr. Craik's practice, twenty-five or thirty acres of horſe-hoed wheat would be as profitable as five hundred acres, according to the above eſtimation. It is true he finds it very difficult to keep down the weeds, that are apt to riſe and multiply the latter end of ſummer; and his intermediate crops of turneps and beans are not ſo profitable as the wheat: but with regard to ſoil and climate, his ſituation is peculiary unfavourable; and his ſucceſs, notwithſtanding theſe circumſtances, is an argument rather in favour

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of the hoeing huſbandry for wheat, as it undoubtedly is of his ſkill and good management.

The expence of a guinea per acre, may be thought low, by thoſe who have not experience of the horſe-hoeing huſbandry, yet ſir Digby Legard's expence was much lower: for in his light land he found one horſe ſufficient for hoeing. And Mr. Wynn Baker, experimenter in agriculture to the Dublin ſociety, and who keeps an exact account of the expence of his horſe-hoeing culture, for the inſpection of the ſociety, found that it amounted only to twenty-three ſhillings and three pence halfpenny per Iriſh acre, ſeed included, and an Iriſh acre is about an acre and a half Engliſh, the proportion being nearly as five to eight.

The particulars of this expence, he ſtates as follows; per acre (Iriſh)

	£.	s.	d.
Ploughing the land once, which is ſufficient after the firſt year, -	0	15	4
Drill-harrowing, 4, 5 or 6, acres a day, with one horſe, - - -	0	0	6½
Carried over,	0	10	10½

	£.	s.	d.
Brought over	0	10	10½
Drilling, from 3 to 5 acres a day, with 2 horses, holder and driver,	0	1	1
Seed, generally 5 stone or 9 gallons, but he charges 6 stone, or near 11 gallons, - - -	0	6	0
Winter-hoeing, with 2 horses. He never hoes less than 2 acres a day,	0	1	7
Spring-hoeing with M. de Chateavaux's miner, with one horse,	0	1	1
Summer-hoeing with 2 horses,	0	1	7
Last hoeing with miner, and 1 horse,	0	1	1
—Weeding and reeping uncertain, not charged,	1	3	3½
Rent,	0	18	0
£.	2	1	3½

Mr. Baker compares the expence and produce of horse-hoed wheat, with that of the common husbandry in Ireland, where he observes their usual method is to fallow the first year, the second to sow wheat, and the third year oats, which finishes the course, and then return to fallowing: so that they have only two crops in three years. The particulars as follows, viz.

	£.	s.	d.
First ploughing for fallow, 8 horses, 8s. two ploughmen, 1s. 4d. two drivers 1s.	0	10	4
First hoeing, 4 horses 4s. driver 6d.	0	4	6
Second ploughing and harrowing,	0	14	10
Third ploughing, called stretching,	0	10	4
Carried over	2	0	0

		£.	s.	d.
	Brought over	2	0	0
Sowing the seed.	Seedsman, 0 8; Eight horses, 8 0; Two ploughmen, 1 4; Two drivers, 1 0	0	11	0
Seed wheat one barrel, or 20 stone, viz. 36 gallons,		1	0	0
Rent for the year of fallow,		0	18	0
Ditto for the year of the wheat crop,		0	18	0
		5	7	0
The expence of the oat crop,		2	5	0
The produce of the acre of wheat, he estimates 9 barrels, at 20s.		9	0	0
And of the acre of oats, 14 barrels, at 6s.		4	4	0
He computes the drilled-wheat crops at 6 barrels per acre,		6	0	0
The expence whereof as stated as above.				
That in 5 courses, or fifteen years, the profit in the common husbandry amounts to		27	19	2
And the profit of the drilled in that time to		52	3	11

The superior profit of the drilled being therefore 24l. 4s. 9d. is 1l. 12s. 3½d. per acre per annum more than the common husbandry.

"The opposers of the drill husbandry, says he, have generally urged, that it is more expensive than the common husbandry, and that therefore it required a greater capital to conduct it. The preceding accounts (upon the faithfulness of which

which my credit ſhall ſtand) ſhews the firſt aſſertion to be wrong, and conſequently the concluſion cannot ſtand. At the ſame time I muſt add, that no man, upon his beginning this culture muſt expect, that he can conduct it upon ſuch low-terms, as he will after having had a little practice; any more than he will know how to build upon the beſt terms, when he firſt engages in it.

" The advocates for the drill-huſbandry, have generally ſtated the produce as being more than the common huſbandry. Perhaps that very circumſtance has been injurious to the ſyſtem. For I am afraid, and indeed I do believe, that when the land ſhall be equally prepared, and the broadcaſt does not happen to lodge, which it is more liable to do than the drilled, that the common ſowing will produce the moſt for one crop; but then the wheat crop conſumes two years, whereas the drill culture produces a crop every year after the firſt.

" The

"The fact to be aſcertained by the two acres of ground already ſpoken of, ſeems to be, which method will produce the moſt corn. But in my judgment, that is not the capital point. The fair queſtion ſeems to be, which of theſe two acres will produce the moſt money, in any given number of years, upon a fair account of profit and loſs; regard always being had to the point of giving the common huſbandry two crops for every fallow. For the aſcertaining this capital and main point, my intention is, to keep the drilled acre under wheat for ſix or nine years; and the other acre under the common courſe of tillage for the ſame time.

"For the preſent I ſhall conclude this ſubject, with only obſerving that wheat raiſed in the drill-huſbandry, will always bring a better price, than that raiſed on the ſame land in the common huſbandry; becauſe it will produce more flour, and is much finer for ſeed-corn.—And that the land under the drill culture, is allways in high condition to be laid down for grafs, which that under the common hufbandry is not."

Mr. Baker defcribes his land, as a grey, ftiff, ftubborn, and infertile foil, lying upon a bed of limeftone, at a fmall depth below the furface. Yet we find, by his account, that two horfes were fufficient for horfe-hoeing it; except, as he mentions in another place, in very hot weather, and then he ufed three horfes. His ridges are five feet broad, and he drills two rows of wheat upon each ridge. He gives but four horfe-hoeings to a wheat crop, and two of them with the miner, which is only a fmall fingle hoe, that goes under the furface; but it does not turn a furrow, and neither changes nor enlarges the furface, which is a great difadvantage to the growing and fucceeding crops; no other inftrument being fo proper for that purpofe as the horfe-hoe, or fwing-plough. And perhaps it was owing to to this, and the intractable quality of Mr. Baker's land, that the ſuperiority of his hoeing culture over the common huſbandry, was not greater than one pound twelve ſhillings and three pence three farthings per acre.

The ſaving of ſo much ſeed in the drill culture, is an object of very great importance: for half the common quantity is ſufficient in drilling upon level ground, or broad ridges, to be hand-hoed. And nearly the ſame proportion is ſaved in cloſe drilling. But for horſe-hoeing, two thirds of what is ſown broadcaſt may very well be ſaved.

Having ſhewn ſome of the advantages that may be expected from this method of culture, confirmed by the extenſive practice of ſeveral perſons, and on land of different qualities; I ſhall next lay before the reader, the principal objections made to it, particularly thoſe made by the author of the Complete Engliſh Farmer; whoſe knowledge of agriculture is conſpicuous;

ſpicuous; but who appears to be prejudiced againſt the new huſbandry, in regard to the cultivation of wheat. I have already taken notice of his miſtake relating to the wide ſpace between the rows; and, as I proceed, ſhall make ſome obſervations upon his other objections.

"The reader, ſays this gentleman in his preface, muſt not expect, in a work like this, many new diſcoveries. It is no part of my deſign to amuſe the world with novelties. I am rather inclined to the practice of the old huſbandry, though I fully and frankly acquieſce in the principles of the new. My reaſon for this ſeeming contradiction is, becauſe I am not without ſome ſuſpicion, that the mighty things which have been ſaid and written of the advantages accruing from the new, are deduced from experiments in *ſmall*, or upon lands of a peculiar kind, and not from a general courſe of practice upon lands of all kinds, confirmed by the experience of any given number of years."

In

In anſwer to this objection I ſhall refer the reader to what is mentioned above, concerning Tull's own ſucceſs, upon land differing in quality, but moſtly light land; Sir Digby Legard's, all light land; Mr. Craik's and Mr. Baker's ſtrong land; and Mr. Deane's, of Woolhampton, near Reading, very ſtrong land, upon which he cultivated wheat in the way of horſe-hoeing above twenty years, with ſucceſs. Mr. Craik takes notice, that he began this huſbandry in a field, where the quality of the ſoil was, as near as he could judge, the average of all the land he employed in this culture; and that the hoeing ſo much improved it, that his crops from it, after a ſix year's trial, continued to be ſuperior to thoſe on his other lands of the ſame quality, that were cultivated later in this manner. And Mr. Baker's experiments of the horſe-hoeing and common huſbandry were made in the ſame field, upon lands adjoining to each other, and of the ſame quality.

"But, ſay the favourers of this huſbandry, it is the uninterrupted ſucceſſion of crops upon the ſame land that gives the advantage. If that, indeed, could be obtained, and the labour remitted, the fact muſt ſtand confeſſed. But five or ſix ploughings, or if you will, horſe-hoeings, are neceſſary in order to the growth of the preſent, and as a preparation for every ſucceeding crop; and five or ſix ploughings cannot be performed without a very conſiderable expence."

The author ſeems here to take it as a ſettled point, that five or ſix horſes-hoeings are the ſame, in point of labour and expence, as ſo many common ploughings. But ſhould he not have taken notice of what Mr. Tull has ſaid upon this head, as he frequently refers to his book on other occaſions?

"In plain ploughing, ſays Mr. Tull, p. 123, ſix feet contain eight furrows; but we plough a ſix feet ridge at four furrows—Now what we call one hoeing, is only *two furrows* of this ridge, which is equal to a fourth part of one plain ploughing; ſo that the hoeing of four acres requires an equal number of furrows with one acre ploughed plain, and equal time to do it in. Except that the land that is kept in hoeing, works much eaſier than that which is not.

"All the tillage we ever beſtow upon a crop of wheat that follows a hoed crop, is equal to eight hoeings, two of which may require four oxen each, one of them three oxen, and the other five hoeings two oxen each. However, allow three oxen to each ſingle hoeing, taking them all one with another, which is three oxen more than it comes to in the whole.

"The expence, then, of hoeing ſix acres in a day in this manner, may be accounted at one ſhilling the man that holds the plough, ſix pence the boy that drives the plough, one ſhilling for the ſix oxen, and ſix pence for keeping the tackle in repair. The whole ſum for hoeing these six acres is three shillings, being six pence per acre. But where there is not the convenience of keeping oxen, the hiring price of hoeing with horses, is one shilling each time."—So that the whole expence of tillage to an acre of wheat, viz. for one ploughing to form the new ridges, and six hoeings afterwards, if done by oxen, is four shillings, and by horses eight.—But here it is to be observed, that this tillage was given to six-feet ridges, with three rows of wheat upon each ridge. But when Mr. Tull altered his ridges to four feet eight or nine inches broad, and two rows upon each ridge, he found four hoeings were generally sufficient, as mentioned above. And when he discontinued the six-feet ridges, that three small oxen were enough for hoeing, at all times: for this he says in his addenda, p. 263.

"I now use no oxen, properly so called, but only bulls, bought in at the time when they are cheapest, and have them castrated.

caſtrated. Theſe are hardier than oxen, though of a leſſer ſize. Oxen being caſtrated while they are calves, grow much larger than bulls. We never put more than three of theſe (they are called bull-ſtags) to a hoe-plough."

Add to this what is ſaid above of Mr. Craik's tillage, and Mr. Baker's, who uſed only two horſes for hoeing, and hoed the crop only four times, and it will appear evidently, that the expences of ploughing the whole ground, and hoeing a fourth part of it are very different; and that four hoeings ſhould not have been charged, as the ſame thing with ſix whole ploughings, as the above author has ſuppoſed in the place above quoted, and in ſome other parts of his work. I ſhall next proceed to what he ſays of weeding, in the preface.

" It is well known, ſays he, to thoſe who are accuſtomed to the culture of land, that in the intervals of well cultivated ground, weeds ſpring up the readieſt and thrive the fasteſt, and that it requires more than ordinary pains to ſubdue them; that in certain rainy ſeaſons this is impoſſible; and that in ſeaſons when it is poſſible, other buſineſs will ſometimes interfere, ſo as to make it very inconvenient to catch every opportunity that offers; and yet if an opportunity is ſuffered to eſcape, the lapſe is irrecoverable. If ſuch be the critical ſituation of hoeing, and ſuch it moſt certainly is, in large concerns, can it be ſuppoſed that prudent men will riſque the ſucceſs of their crops upon ſuch uncertainties?"

This, it muſt be acknowledged, is an objection of ſome weight; weeds being great enemies to farmers, in both the old and new huſbandry. The author, indeed, ſeems to think, that in the new huſbandry it is not poſſible to ſubdue them, and that if they are not ſubdued, they will deſtroy the crop. But we cannot in this caſe argue fairly from the old huſbandry to the new; becauſe the farmers in the old huſbandry are often bringing a new ſtock of weeds to their lands, in the dung and other manures they lay upon them, and can never totally ſubdue the weeds, by ſometimes a fallow, and the common change of crops.

But in this reſpect the horſe-hoeing huſbandry is very different; no dung, or other manure containing any ſeeds of weeds, are laid upon horſe-hoed wheat; but on the contrary, the ſtock of weeds are diminiſhed by hoeing and weeding; and by that means they will be ſubdued, with proper care, which is neceſſary in every method of huſbandry. Mr. Craik's land is, indeed, an exception, as in ſome years he found it impracticable totally to ſubdue the weeds. But his ſituation is ſingular, and cannot be any juſt objection to the hoeing culture in general. Yet his courſe of two or three drilled wheat crops, beans, and turneps, is much more more profitable than the common courſe in the old huſbandry. It is undoubtedly neceſſary that thoſe who would practiſe the new huſbandry for wheat, ſhould firſt make their land very clean by fallowing, or hoed crops of turneps or other large plants, and then it may be kept ſo; unleſs weeds can multiply by equivocal generation.

"Moreover, in ſtiff clays, neither the drill nor the horſe-hoe can be introduced, generally ſpeaking, to advantage. Land of this ſtubborn nature can ſeldom be brought to ſuch a tilth as to admit of either; for land muſt be made very fine before the moſt perfect drill-plough that I have ever yet ſeen, can work with that degree of certainty as is neceſſary to plant equally the reſpective rows: and in ſummer, when the aſſiſtance of the horſe-hoe is moſt wanted, ſuch ſoils are apt, if the weather be dry, to be ſo hardened as not to be removed without annoyance to the rows; and if wet, clay is ſo tenaceous of rain, and ſo poachy, that any attempts to looſen the ſoil in that ſituation, would ſerve only to compreſs it. The horſe-hoeing

hoeing husbandry therefore can never be the general husbandry of England, where at least two parts in three of the arable lands are clay."

A considerable part of the arable lands in England is strong, but that they are clay, properly speaking, will not readily be admitted. It is likewise undoubtedly true, that strong stubborn soils are of difficult culture, in every mode of husbandry: but as appears above, not impracticable in the drill culture. For it is to be observed, that such strong lands and even clays are cultivated for wheat in the old husbandry, and with the same kind of instruments as are used in the new, to prepare them for drilling. Ploughs and harrows, and of late the spiky roller, are the instruments employed to reduce and prepare strong land, to be sown broadcast, and the very same are applicable to such land to prepare it for drilling: for when a drilled crop is carried off, the ridges upon which it stood, are to be ploughed

for

for another crop, as in common ploughing, with this advantage, that above three fourths of these ridges are well prepared for it, being broke and reduced by the several preceding horse-hoeings, and no long roots of couch, or other rank weeds in it, to bind the soil. And for the same reason, the middle of the ridges, upon which the two rows of wheat stood, being only about fourteen or sixteen inches in breadth, are more easily ploughed by two furrows, than can be done in common tillage; where the land is sometimes stale, and is generally bound and held together by the roots of weeds or clover. The fact therefore is, that these small ridges are more easily cultivated and prepared for a succeeding crop of wheat, than can be done by the old husbandry, in the same sort of land.

As to the objection that such soils are apt, if the weather be dry, to be so hardened as not to be removed by the hoe-plough, without annoyance to the rows; thoſe who have cultivated wheat with the horſe-hoe in ſtrong land, have not found this inconveniency, ſo as to prevent that operation. The hoer's attention is engaged to keep his land in good tilth; and in dry ſeaſons and very ſtiff land, this is very difficult to be done with the plough or harrow. But Mr. Tull has recommended another inſtrument for breaking ſuch dry hard ſoil, a ſtone roller, that is very effectual in the horſe-hoed intervals, which are about four feet wide.

"This ſtone cylinder, ſays he, p. 200, is two feet and a half diameter, and weighs eleven hundred weight beſides the limbers, muſt never be uſed but in the drieſt weather, when neither the plough nor harrows can break the clods, and then being ſo very ponderous and ſhort, only three feet long, it cruſhes them to powder; or into ſuch very ſmall pieces, that a very little rain, or even the dews, if plentiful, will diſſolve them.

"I have

" I have had great benefit by this roller, in preparing my ridges for turneps. The weather proving dry at midſummer, which is the beſt ſeaſon for planting them, the land was in pieces like horſe-heads, ſo that there was no hopes of reducing them fit for planting with turneps that year; the clods being ſo very large that they would require ſo many viciſſitudes of wet and dry weather to ſlack them; but this inſtrument cruſhed them ſmall, and the plough following it immediately, the ridges were harrowed and drilled with very good ſucceſs.

" I have often made uſe of it for the ſame purpoſe, in the middle of a cloddy field, where it pulverized the clods ſo effectually, that the benefit of it might be plainly diſtinguiſhed, by the colour and ſtrength of the two following crops, different from the other parts of the field adjoing on both ſides, whereon the rooler was not drawn.

" But

"But crushing has such acontrary effect from squeezing, that if this roller should be used when the land is moist, it would be very pernicious, by unpulverizing it; of which I am so cautious, that sometimes I let the roller lie still, for a whole year together."

Such a roller, therefore, will speedily reduce the hard clods in the four-feet intervals, at any time in summer, and the pulverized earth being then turned up to the rows on each side by the hoe-plough, will not be liable to become hard again before the next hoeing, when the same earth is to be turned from the rows of wheat into the intervals, which will not annoy the rows, whether the earth is then dry or moist.

As to making attempts to loosen strong land by the plough, while it is wet; that, as the author observes, would serve only to compress it, which is a truth known to every experienced husbandman, and none such do attempt to plough strong land in that

that condition, with a view of loofening it. This is therefore no valid objection to the hoeing of ftrong land, which, though not proper to be done while it is wet, can be foon brought into a proper temper for it, upon the return of dry weather.

To the objection relative to drilling, that the drill-plough cannot be introduced in ftiff clays, the author fhould have recollected, that in preparing land for drilling the middle of the new ridges whereon the wheat is to be drilled, is compofed of the mould of the former intervals, which having been feveral times horfe-hoed in the fpring and fummer is not ftale and hard like common untilled land, but more refembling land that has been well fallowed; and if the owner thinks it convenient, he may plough up the intervals to form the new ridges, and drill upon the frefh tilth. But for doing this there is no abfolute neceffity. The fhares of the drill-plough, are not above

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an inch in thickneſs, and enter only about three inches into the ground. And without doubt a drill may be made to penetrate ſtrong land to this depth. Our author, if he has ſeen no other drill-plough but Mr. Tull's, may juſtly think ſuch not ſtrong enough for clays; but there is no difficulty in making one of ſufficient ſtrength to drill wheat upon very ſtrong land, prepared in the above manner.

"New methods of huſbandry, continues our author, that are to exclude the old, ſhould have every degree of evidence to ſupport them, that eaſe in the practice, and profit in the iſſue, are capable of producing. They ſhould not only be more ſimple and more expeditious in the execution, but more certain and more copious in their produce. If upon repeated trials, any ſuch new method of huſbandry was to be propounded, and if the advantages of it were to be confirmed, by the moſt convincing of all arguments, the

the enrichment of the practisers, then indeed nothing but obstinacy, or infatuation, could be alledged for not relinquishing the old and embracing the new. But if upon an impartial comparison of the merits of the new husbandry, so strongly recommended in books, with those of the old, so tenaciously adhered to by the body of farmers, we find the very reverse of this generally the truth; it is to be wondered at, that a sober and sensible set of men, should adhere to the solid, approved, and experienced maxims of their fathers; and that they should reject this novel husbandry, and refer it to less experienced undertakers; who, like adventurers into new regions, believing the reports of the first discoverers, expect to draw riches from every soil, and make a fortune upon every farm."

Whether the author's account of the hoeing culture may not contribute to the farmers dislike of the new husbandry, and their declining to make any trial of it, ſeems not improbable. The ſix-feet ridges, the manner of forming them, and the ſubſequent horſe-hoeings, deſcribed by the author, were as practiſed at firſt by Mr. Tull; but that practice upon further experience he exploded, and recommends one more ſimple and more profitable. This ſhould have been propoſed to beginners: let any perſon read the account given by Mr. Craik of this culture, and they will perceive with what eaſe it may be performed. Nothing difficult is found there, in the manner of forming the new ridges, which differ in nothing material from the common practice of farmers, in forming ridges of the ſame ſize: the horſe-hoeings alſo, are performed in the ſame manner as common ploughing, and which every ploughman can perform, who can uſe the common ſwing-plough. The circumſtances of the weeds ſpringing up in Mr. Craik's, is an accident merely local, and by no means incident to this huſbandry in general, as he has remarked. The profit likewiſe is ſuch as might encourage any perſon to make trial of it, who has not been prejudiced againſt it; and his drill-plough is of ſo ſimple a conſtruction, that any perſon may conduct it at the firſt trial, and may be made ſtrong enough to drill wheat upon any land prepared by this huſbandry.

Notwithſtanding the author thus labours to depreciate the horſe-hoeing culture, he ſpeaks candidly of the author of it; approves of the principles; and acknowleges that the old huſbandry has received great improvements from the new: as in the following paſſages.

" But nevertheleſs, the memory of Mr. Tull ought to be held in the higheſt reverence by every huſbanman, for his improvement of the art of agriculture. It is from him we have learned the great benefit of frequent ploughings to pulveriſe the ſoil, which in ſome ſituations ſupply the place of dung. To him the farmer

owes

owes the advantages arifing from cleanf-ing and preparing his ground, by fowing of turneps, and improving them by hoe-ing. It was Mr. Tull who firft intro-duced the drilling of peafe, beans, vetches, faint-foin, &c. into field culture, and fhewed the advantages of hoeing and keeping them them clean from weeds. And it is from him, that the whole king-dom have learned to raife more corn from lefs feed than ever was thought poffible, before he fet the example. Thefe are fo-lid and fubftantial advantages, which have introduced an univerfal reform in hufbandry; though his method of adapt-ing his own practice to his own principles, has not generally obtained." See preface, p. 18.

And p. 175. "It muft be acknow-ledged, that even the old hufbandry has re-ceived no fmall improvement, by the dif-covery of the genuine principles of the new. The advantages of meliorating and pulverizing the earth are better underſtood, and I believe more generally practiſed, than formerly; and the grand principle of all, that of frequently ſtirring, expoſing, and enlarging the ſuperficies, in order to ſupply, in ſome meaſure, the place of dung, is a diſcovery of vaſt importance.

"While we hold theſe principles in view, we cannot go far aſtray: for all that ſeems neceſſary to be done, is to keep our land in ſuch a kind of temperature, as neither to be too hot nor too cold, too looſe nor too much bound, too wet nor too dry, too light nor too heavy; but in all our improvements to endeavour to approach as near as poſſible to that happy mixture which nature has exhibited to our imitation, in the rich meliorated black mold already deſcribed; that whether it is wrought by the ſpade, or barely turned up by the plough, diſplays its fertility by a voluntary diſcontinuity of its parts, and a grateful diſcharge of its fragrance.

"This

"This ſeems to confirm to us the juſtneſs of the Tullian principles, by pointing out the neceſſity of ſweeting and meliorating our land, by frequently expoſing it to the action of the ſun and air, and of ſeparating its parts by repeated plowings. Hence we may learn, that in preparing our land for any kind of grain, we ſhould be leſs ſparing of our labour than of the dung cart, and that of all compoſts, thoſe of earths with earths are the moſt natural."

The author's obſervation is very juſt, that the mixture of earths is the moſt natural, and I may add the moſt laſting improvement of land; but the misfortune is, that it cannot in practice be generally introduced. The expence of it, in moſt caſes, is too great for common farmers; who being unable to make extenſive and laſting improvements in that manner, muſt be contented to correct the imperfections of their land with manures from year to year; the expence whereof is alſo very great, but not neceſſary to be laid out at once.

Is it not a great recommendation of the horſe-hoeing culture, that the land receives by it all the advantages above mentioned? That it ſweetens and meliorates the ſoil, and more frequently expoſes it to the action of the ſun and air, than can be done in any other method of huſbandry. One dreſſing with dung, as ſtated by our author, and by other practical huſbandmen, coſts above five pounds per acre, which is more than three times the whole expence of an acre of horſe-hoed wheat.

But to proceed, the objections made by the author to this huſbandry, ſeem to ariſe from his own ill ſucceſs in ſome trials he made of it; and not being particularly informed of the ſucceſsful practice at large of any other beſides Mr. Tull, as may appear by what he ſays farther, p. 188.

"And now after all, ſays he, though *the caſualties I have met with*, have rendered

dered me cautious of recommending this huſbandry to the general practice, in preference to the old huſbandry, yet I cannot be excuſed, were I to conceal the real advantages that attend it; and they are ſo well deſcribed by Mr. Tull, that I ſhall give them in his own words.

" Firſt, ſays he, we can augment our crops by increaſing the number of ſtalks, from one, two, or three, to thirty or forty, in ordinary field land.

" Secondly, by bringing thoſe ſtalks into ear. For if it be diligently obſerved, not half the ſtalks of wheat ſown in the ordinary way come into ear.

" Thirdly, by enlarging the ſize, and multiplying and filling the grains in the ears.

" Thus, adds he, by encreaſing the number of ſtalks, bringing more of them up into ear, making the ears larger, and the grain plumper and fuller of flour, the horſe-hoeing method makes a greater crop from a tenth part of the plants, than the ſowing method can."

"Another advantage, continues our author, attending the new huſbandry, and, in my opinion, a very conſiderable one, is, that in wet ſummers, if any ears are blighted (or ſmutty) they ſtand erect, while the ſound ears bend almoſt down to the ground; ſo that a man may walk between the rows, and clip off every blighted ear, without leaving one to affect the crop.

"As a very natural concluſion to this account of the culture of wheat in the new huſbandry, I ſhall produce ſome late experiments, becauſe manifeſtly derived from, and dependent upon the true Tullian principles. The firſt is authenticated by the relation of Dr. Watſon who has reported an experiment, made by Mr. Charles Miller, ſon to Philip Miller, eſq. the celebrated botaniſt, by which it appears—That having in the autumn of 1765 planted

planted a ſingle grain of wheat, in the botanic garden at Cambridge; in the ſpring of 1766 he divided the ſeveral plants that tillered from that grain, and tranſplanted them into freſh earth, by which near two thouſand ears were produced from the firſt ſingle grain. On the ſecond of June, 1766, in order to repeat the experiment, he ſowed ſome grains of the common red wheat, and on the eighth of Auguſt he ſelected a ſingle grain, which had produced eighteen plants; each of theſe plants were planted out ſeparately; and ſeveral of them having puſhed out ſide-ſhoots, thoſe likewiſe were divided, and again tranſplanted. The whole number thus tranſplanted before the middle of October, amounted to ſixty-ſeven plants; theſe remained through the winter vigorous, and in the ſpring of 1767, were again divided and tranſplanted; and from the middle of March to the twelth of April, five hundred plants in all were produced, which were ſuffered to grow without any further divifion, and when ripe were gathered, and the number of ears thus produced from one grain was twenty-one thoufand one hundred and nine; fome of the plants producing one hundred ears from a fingle root, and fome of the ears feven inches long."

Another experiment mentioned by our author, was made formerly by Thomas Everard, efq. of Southampton, who planted fome wheat which he had fteeped in a compofition of his own invention, viz. ftone-lime, nitre, and pigeon's-dung, with rain-water; and then planted the wheat in fingle grains about ten inches apart. Several of the grains produced fixty, feventy, and from one eighty ftalks, with very large ears, full of large corn, many of the ears being fix inches long, and had above fixty grains, and none lefs than forty.—The fediment that remained of the compofition, he mixed with four times the quantity of common earth, and laid it up in the fhade the whole winter, turning

turning it now and then to incorporate the mixture with the mould; and at the time for planting peaſe, he cauſed ſpade holes to be dug, about ſix inches apart, and in every ſpade-hole he put a ſmall quantity of the mixture, in which a garden pea was ſet, and covered with the common mould. The reſult was, that the peaſe grew to an uncommon height, not leſs than nine feet, were furniſhed with pods of an uncommon ſize, and ſupplied his table with green peaſe the greateſt part of the ſeaſon.

Theſe experiments ſhew the wonderful fertility of theſe plants in rich garden ground, and the advantage of allowing them room, to which probably, more than to the ſteep, was owing the great encreaſe of Mr. Everard's wheat; for we ſee that hoed plants multiply greatly in common unmannured ſoils, though not ſteeped.

I have had from ten or twelve to twenty-eight ſtalks of wheat, each from ſingle grains

grains planted in double rows, and the ears containing about forty grains a piece, upon very ordinary land, hand-hoed: this is a great increafe, though far fhort of fome of the above. In broadcaft fowing, fome grains of wheat produce eight, ten, to eighteen or twenty ears, where they happen to ftand fingle; but in general, wheat fown broadcaft, does not produce two ears from each grain fown. For admitting that a middling ear contains only twenty grains, and two fuch ears forty grains of marketable wheat, this is an increafe of forty times the feed fown. But the quantity fown being at an average not lefs than two bufhels and a half per acre, forty times that quantity is one hundred bufhels per acre; which is probably near five times as much as is produced annually throughout England, on an average of years and crops, on all forts of land. By which it appears that four bufhels out of five fown are loft, or killed by froft, devoured by birds, &c.

"In

"In the profecution of this experiment, continues the author, I cannot help giving this caution. That as it appears both from Mr. Miller's experiments, and from the experiment above related, that the grains of wheat muft have room to extend their increafe, care fhould be taken in fowing, that the feed may be fpread as equally as poffible, but not too thick. Upon moderately good land, half the quantity of feed thus prepared, may fuffice, to what in the ordinary way is commonly fown. I know how hard it will be to perfuade the hufbandman to practife this frugality: he may, however, fafely try a few lands at firft, and as he finds the effect, let him continue, or difcontinue the practice the future."

The author here recommends thin fowing, though he before objected to the fmall proportion of ground planted for horfe-hoeing; yet much more feed is allowed in that way than Mr. Everard's experiment. Agallon of c ommon lammas

mas wheat contains about 80,000 grains, and ſix gallons, the quantity uſually drilled upon an acre, for horſe-hoeing, contains about 480,000 grains, and upon Mr. Everard's land was planted at the rate of 62726 grains per acre; viz. the quantity drilled is above ſeven times as much as the other. The large ſize of the ears in the experiment is mentioned, but not the crop produced upon any certain meaſure of ground. The increaſe of the horſe-hoed wheat, is from thirty to forty gallons for each gallon drilled; and the increaſe from wheat ſown broadcaſt, not above one third part ſo much, though the broadcaſt is manured, the drilled not. This great difference is therefore owing to the hoeing culture, and keeping the land clean from weeds.

There is a method of culture lately introduced, as Mr. Young takes notice, by Dr. Hunter of York, called the alternate huſbandry; about three or four yards in breadth is ſowed with wheat broadcaſt,

and

and the ſame breadth is followed, and thus alternately throughout the field. The following year the wheat ſtubble is ploughed up for a fallow, and the laſt year's fallow ſowed with wheat. Some manure is beneficial, but not ſo much neceſſary as in the common huſbandry. The crops obtained this way, are from twenty to twenty-four buſhels per acre. The gentleman who introduced this method, recommends it for weak arable land, where manure is ſcarce.

The author of the Complete Engliſh Farmer ſays that this method is liable to none of the objections which have hitherto retarded the progreſs of the new huſbandry, and yet it ſeems to promiſe all the advantages of it; being managed with the ſame inſtruments that the common huſbandry ſervants have been accuſtomed to, that it is ploughed and ſowed in the ſame way, or nearly ſo, and may be hand-hoed if the weeds become rank. This, however, is an advantage, only when the

the wheat is planted in rows; otherwiſe the ſame method of hoeing is equally applicable to wheat ſown broadcaſt in the common way.

"That this method, ſays he, will be profitable where dung is ſcarce, cannot be doubted: for it is now univerſally acknowledged, that though tillage has not all the properties of dung, and therefore cannot wholly ſupply the want of it, yet, where it is properly performed, it does much more towards fertilization than dung of itſelf can without proper tillage. And we may ſafely conclude from Mr. Tull's experience, that the longer any field is cultivated in this manner, the richer and more fertile it will grow.

"I know it will be ſaid by others, becauſe my ploughman has already ſaid it; What can you think to get by ploughing half your lands? does it not double the rent? True, but it leſſens the labour and expences. Seed, and time of ploughing and ſowing are ſaved. But he adds, you

do

do not intend to ſave ploughing; for inſtead of three times ploughing for wheat, if you plough as often as the weeds ſpring up, you muſt plough once a month. Admitted that in ſummer I may, this then will be ſix times ploughing one half, which will be equal to three times ploughing the whole; but this will be the greateſt part of my expence.

"Dung, where my farm is ſituated, coſts five ſhillings a load, beſides fetching two miles: three ſhillings a load, and to fetch it ſix miles; one ſhilling and ſixpence a load, and to fetch it thirteen miles. Dunging an acre, at fifteen loads to the acre, cannot, therefore, be eſtimated at leſs than four guineas at an average, one half of which may certainly be ſaved.

"As to the produce it may be eſtimated upon good authority, at three quarters upon an acre. This I report upon the credit of a gentleman, who firſt deviſed this new method; and I am the rather inclined to believe the fact from this consideration, that in most inclosures in the common method of husbandry, the furrows and water-furrows take up a considerable space, and produce little or nothing. In this method the furrows are made deep, as in the new husbandry, upon the edges of the intervals, and take nothing from the lands that are sown: these furrows lie open all the winter, by which the superfluous wet is drained off from the wheat; and then, when the spring season returns, they are filled up with fresh earth from the interval, which gives vigour to the vegetating roots, and affords an easy passage for them to spread. This advantage, with the additional tillage, it may be presumed, will ballance the deficiency of ground; especially when it is considered, that Mr. Tull had often, upon two rows in six-feet lands, at the rate of five quarters of wheat on an acre."

This method, it is said above, seems to promise all the advantages of the new hus-

husbandry, but upon a fair comparison will be found inferior to it. Let us, for example, take an acre of each, and admit that the crops in these two methods are equal, upon equal quantities of land sowed. An acre in the alternate husbandry is half of it sowed with wheat each ear, and the other half of it is fallow. And therefore when it is said, that an acre in this husbandy produces three quarters of wheat, it is to be understood, that a whole acre is sowed with wheat to produce that quantity, and another acre under a fallow: otherwise, if meant of a single acre, half cropped and half fallow, this would be six quarters of wheat upon every acre sowed, at an average. A quantity not to be expected from very good land; whereas the gentleman who introduced this method, proposes it for thin weak land, where manure is scarce. In comparing the two methods, therefore, we must reckon the expence and produce of two acres of the alternate husbandry, and compare them to the produce and expence of one acre of the horſe-hoed. The crops in the two methods may be reckoned equal, and the expence as follows.

New Huſbandry.

	l.	s.	d.
One whole ploughing to form the new ridges, —— ——	0	5	0
Four horſe-hoeings with the hoe-plough,	0	5	0
Seed three pecks, at 5 ſhillings per buſhel,	0	3	9
Drilling the ſeed, — —	0	0	6
Hand-hoeing the partitions, ——	0	2	6
Hand weeding the rows, ——	0	1	3
Reaping, —— ——	0	3	0
£.	1	1	0

The hand-weeding is ſtated high, and twice hand-hoeing, though that is often done but once to a crop. The reaping uſually coſts about half the price of the ſowed wheat.

The Alternate Huſbandry.

	l.	s.	d.
Six ploughings of the fallow acre,	1	4	0
Dung, —— —— —	1	1	0
Seed, 9 pecks, —— ——	0	11	3
Reaping one acre of wheat, ——	0	6	0
£.	3	2	3
The expence of the alternate huſbandry exceeds the drilled, £.	2	1	3

Nothing

Nothing is chared for harrowing in either method, which is in favour of the alternate way, that requiring moſt harrowing. The ploughings alſo are charged but four ſhillings per acre, and to the hoed acre five ſhillings. It is ſaid above, that in the alternate method half the common quantity of dung may be ſaved; and here only one quarter is charged. Yet it appears that the alternate huſbandry, coſts double the expence of the drilled; to which muſt be added the year's rent of the fallowed acre. Hence it is evident, that the hoeing culture is much more profitable than the alternate.

If the land to be fallowed is laid up in one-bout ridges, the tillage may be done cheaper than when laid flat, or into broad ridges; and ſix ploughings may not be always neceſſary, though they will more improve the land than four or five, if the weather is favourable. On the other hand, the horſe-hoings will not coſt ſo much as above, if the double mould-board plough is made uſe of, to turn the mould up to the rows, inſtead of the hoe-plough.

I have charged ſome dung to the alternate huſbandry, in compliance with what is ſaid above, and by the deviſer of this huſbandry; and no doubt it will be of ſervice in land not over-rich. There is notwithſtanding ſome reaſon to think, that dung is not neceſſary in this method, provided care is taken to fallow the land very well, by repeated ploughings and harrowings throughout the ſeaſons, till ſeed-time. If the dung can be all ſpared, the expence of this method will be conſiderably reduced, though not ſo low as the new huſbandry.

The alternate huſbandry is ſuppoſed to produce three quarters of wheat per acre per annum; which, at five ſhillings per buſhel, is ſix pounds for each crop; from which deducting three pound three ſhillings and three pence, the annual expence, there remains two pounds ſeventeen ſhillings and nine pence profit per acre, from weak poor land; a profit much exceeding the general run of arable land ſown with wheat without manure, or with a ſmall proportion of it; which ſhews that the crops are ſtated too high at the three quarters per acre on ſuch land, at an average. On the other hand, ſuch land in the horſe-hoeing culture, and no manure, will not at an average produce annually three quarters of wheat per acre. For though good land ſo cultivated will produce four quarters per acre, and as above mentioned Mr. Craik's crops were ſo much, and Mr. Tull's often five quarters per acre on his beſt land; yet, by an account he took one year of the hoed wheat upon his land in general, amounting to above one hundred acres, it appears that the crop upon an average, was only about twenty buſhels per acre. And Sir Digby Legard's crops of horſe-hoed wheat upon the Yorkſhire wolds, was but about ten or twelve buſhels per acre. He ſays, indeed, that his crops were ſo ſmall, partly on account of their want of experience at firſt, and that when the hoeings were performed better, the land and crops were much improved; though his firſt crops, imperfectly as they were managed, were much ſuperior to thoſe of the common huſbandry there. The wold farmers in that part of the country have no manure for their wheat but the ſheepfold, and their average crops of wheat are but four buſhels per acre. It is indeed very common in eſtimating crops to over-rate them, in every mode of huſbandry; and therefore I have taken notice of thoſe chiefly that were authenticated by actual meaſurement.

But though it appears upon the compariſon, to be a method inferior to the hoeing culture, it ſeems, in point of profit, to be preferable to the old huſbandry. The method does not much differ from that of the ancient Romans, of fallowing every ſecond year, which is ſtill the practice in ſome parts of Italy and Switzerland; though their fallowing ſeems to be very ſlovenly performed: for in the territory or neighbourhood of Geneva, where it is the common huſbandry to fallow their fields and ſow wheat alternately, they have exceeding poor crops, viz. but about three buſhels in return for one buſhel ſowed. This we are aſſured is the common produce of that country by M. De Chateauvieux of Geneva, and that he had no more from his fields, which were cultivated in the manner of the country, and an exact account kept of the produce of them for many years. Nor were theſe poor crops wholly owing to to the native poverty of the ſoil, but to their bad culture. For when that gentleman, in proſecuting the new huſbandry, had brought his land into good tilth, and ſubdued the weeds, his crops were greatly improved.

Fallowing is beneficial to land, not only in conquering weeds, but likewiſe as it enriches the ſoil, to a degree equal, or even ſuperior, to a common dreſſing with dung. But to have this effect the land muſt be often cultivated, and no weeds ſuffered to grow rank, much leſs to run to ſeed. The horſe-hoeing huſbandry is a ſpecies of fallowing, producing a crop, and at the ſame time remarkably improving the land; the following inſtances of this, from Mr. Tull, are very obſervable, p. 127.

" A piece of eleven acres of a poor thin chalky hill, was ſown with barley in the common manner, after a hoed crop of wheat, and produced full five quarters and a half to each acre (reckoning the tythe) which was much more than any land in all the neighbourhood yielded the ſame year; though ſome of it be ſo rich, as that one acre is worth three acres of this land: and no man living can remember, that ever this produced above half ſuch a crop before, even when the beſt of the

the common management has been beſtowed upon it.

"A field that is a ſort of heath ground, uſed to bring ſuch poor crops of corn, that heretofore the parſon carried away a whole crop of oats from it, believing it had been only his tythe. The beſt management that ever they did or could beſtow upon it, was to let it reſt two or three years, and then fallow and dung it, and ſow it with wheat; next to that with barley and clover; and then let it reſt agaiu: but I cannot hear of any good crop that it ever produced, by this or any other of their methods. It was ſtill reckoned ſo poor, that nobody cared to rent it. They ſaid dung and labour were thrown away upon it. Then, immediately after two ſown crops of black oats had been taken off it, the laſt of which was ſcarce worth the mowing, it was put into the hoeing management, and when three hoed crops had been taken from it, of turneps and potatoes, it was ſown with barley,

barley, and brought a very good crop, much better than ever it was known to yield before; and then a good crop of hoed wheat succeeded the barley: and then it was again sown with barley, upon the wheat stubble; and that also was better than the barley it used to produce.

"Now, all the farmers in the neighbourhood affirm, that it is impossible but that this must be very rich ground, because they have seen it produce six crops in six years, without dung or fallow, and never a one of them fail. But, alas! this different reputation they give to the land, does not at all belong to it, but to the different sorts of husbandry: for the nature of it cannot be altered but by that, the crops being all carried off it, and nothing added to supply the substance those crops took from it, except (what Mr. Evelyn calls) the celestial influences, and that these are received by the earth, in proportion to the degrees of its pulveration."

Another example is given by him of the effects of good tillage, p. 21, as follows. "It is of late fully proved by the experience of many farmers, that two or three additional ploughings will ſupply the place of dung, even in the old huſbandry, if they be performed at proper ſeaſons; and the hiring price of three ploughings, after land has been thrice ploughed before, is but twelve ſhillings; whereas a dunging will coſt three pounds. This was accidentelly diſcovered in my neighbourhood, by the practice of a poor farmer, who, when he had prepared his land for barley, and could not procure ſeed to ſow it, ploughed it on till wheat ſeed-time; and, by means of ſuch additional ploughing, without dung, had ſo good a crop of wheat, that it was judged to be worth more than the inheritance of the land it grew on."

Theſe examples ſhew evidently the improving effect of tillage, without the aſſiſtance of manure; but as in this laſt

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inſtance, one crop only was obtained in two years, it might be doubted whether ſuch huſbandry would be profitable if continued; we have an example of this in Mr. Maxwells collection; where ſpeaking of this circumſtance of the poor farmer mentioned by Mr. Tull, he relates one ſimilar to it, of a poor farmer, tenant to Sir John Paterſon, in Lothian, near Edinburgh; who being likewiſe unable to buy ſeed for a field he had prepared for barley, continued to plough it till autumn, and then ſowed it with wheat; and reaped ſo large a crop, that he was thereby encouraged to extend this method of huſbandry to his whole farm; by which he came, in ſome years, to be in circumſtances to have purchaſed the farm.

This has nearly the ſame advantages with the alternate huſbandry. In the latter way the air has a more free paſſage between the ſowed lands, which is a benefit to the crop. On the other hand, when a whole field is fallowed, it may be

more

more conveniently croſs-ploughed than in the alternate way. The great diſadvantage in both theſe methods is, that only half the land is ſown every year; and admitting that an acre produces three quarters of wheat, when an acre is ſown, this is but half that quantity, or twelve buſhels per acre, throughout any extent of land cultivated in either of theſe ways; becauſe, as above obſerved, in the alternate method only half the land is ſown; and in the other the whole is ſown but once in two years; and both are loaded with a double rent: the horſe-hoed produces a better crop of wheat every year upon the ſame quantity of land, at a ſmaller expence, alſo without manure, or the land being impoveriſhed; but on the contrary it will be improving annually, as appears from experience.

MISCELLANEOUS

DISSERTATIONS

ON

RURAL SUBJECTS.

On the force of running water, &c.—To compute the quantity of water of a river, brook, &c.—To make a half-second pendulum for this use.—Of undershot mills, and dimensions of one measured by the author.—The velocity and quantity of water to this mill, and the work done by it.—Experiments to determine the velocity and quantity of water through different apertures.—A general mistake relating to them rectified.—A valuable improvement in the wheels of undershot-mills.—Of overshot-mills, their advantages and defects.—Compared with undershot-mills from experiments.—Of breast-shot mills.—The dimensions of one measured by the author.—These three sorts of mills compared.—The quantity of water that each of them require.—The quantity of water in the Thames, at Westminster-bridge.—Of the force, impulse, or momentum, of running water.—Of the bottomwork of mills and other machines.—The best method of constructing them, to prevent blowing.—Of coffer-dams made use of in building the piers of bridges.—Of Daggenham breach.—Of Archimede's screw-pump, and how constructed.—Of the best kinds of mortar for the bottoms of water-works.—Of making canals to conduct water for mills and other engines.—The manner and expence of making them.

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EXPERIMENTAL DISSERTATION

ON THE

FORCE of RUNNING-WATER, &c.

THE extenſive uſe of water for mills and other machines is generally known; but the manner of conſtructing ſuch machines, and the application of the water to produce the greateſt effect, is not ſufficiently underſtood and attended to; the conſtruction of them being, for the moſt part, left to perſons not well ſkilled in the principles of mechanics and force of running-water. To give ſome aſſiſtance to thoſe who would erect or improve works of this kind, that they may receive the full benefit of the

 water,

water, and make the bottom work ſtronger and more durable than is commonly done, is the intention of this diſſertation.

In erecting mills two circumſtances are to be well conſidered, namely, what quantity of water can be obtained from the ſtream or river to be employed; and to what head or height it can be raiſed: upon theſe two the force or effect of the water, and the benefit to be expected from it, principally depend.

To know what quantity of water any river, brook, or ſtream will yield for this purpoſe, the depth and velocity of the ſtream is to be examined, under a bridge, or at ſome other convenient place, where the banks are perpendicular, and the ſtream is nearly of an equal depth and velocity. Having meaſured there ſix or eight yards in length, and placed marks at each end, then thrown in, a little above the uppermoſt mark, an apple, orange, or ſome other light body, that will

will partly ſink into the water, and the reſt appear in ſight above it; and being provided with a half ſecond pendulum, obſerve what number of vibrations is made by the pendulum, while the body is paſſing from the upper to the lower mark in the middle of the ſtream. Repeat this ſeveral times, which being accurately done, the medium of theſe trials will determine, ſufficiently exact, the velocity of the water in that ſection of the river.

A ſmall ball of lead or braſs ſuſpended by a thread, whereof the length, from the point of ſuſpenſion to the center of the ball is 39,2 inches, ſwings ſeconds. And one of one fourth part of that length, viz. 9,8 inches, ſwings half ſeconds. The thread may be of ſilk, or very fine braſs-wire may be uſed. Such a half-ſecond pendulum is very convenient for this uſe; but to make it exact, it is proper, before it is uſed, to compare it with a good clock, the pendulum of which ſwings ſeconds.

Suppoſe, for example, that the length of the ſtream marked out was 22 feet, through which the body paſſed in 18 vibrations, or 9 ſeconds: that the breadth of the river there was 12 feet, and depth $1\frac{1}{2}$ foot; theſe multiplied together, $12 \times 12 \times 1\frac{1}{2}$, the product 264 is the number of cubic feet of water in that ſection, which paſſes through it in 9 ſeconds; this is 44 cubic feet of water per ſecond, that this ſtream would furniſh for the uſe of the mill, at the time the experiment was made.

Common river or ſpring-water is found by experiment to weigh 1000 ounces, or $62\frac{1}{2}$ pounds averdupoiſe per cubic foot; 44 cubic feet therefore weighs 2810 lb. or 1 ton 5 cwt. and 10 lb. at 20 cwt. per ton.

The velocity of ſuch a ſtream is greateſt towards the middle of it, and at the ſurface

face of the water; being ſomewhat retarded in its motion near the ſides by the friction againſt the banks, and towards the bottom by weeds, ſtones, &c. And if the water is deep, it commonly runs quick near the ſurface, and ſlower towards the bottom: for which reaſon, in making this experiment in deep water, it is proper to uſe two balls, faſtened together by a thread, one ball to ſwim at the ſurface, and the other near the bottom. The top ball will go on foremoſt till the ſtring is ſtretched, and then both balls will proceed with the uniform motion of the ſtream. Theſe balls may be made of wax, and by incloſing in the balls a little lead, or ſome other heavy matter, the lower ball may be made of the ſame ſpecific gravity as the water, or a little more; and the upper ball to ſwim at the ſurface of the water, ſo as a ſmall part of it to be juſt viſible. This is ſometimes neceſſary to prevent the wind having any effect upon it.

In the ſhallow places of a river, the water runs quick, and ſlow where it is deep, and the ſame quantity paſſes through every part of it; for which reaſon the quantity found to paſs through one ſection, determines how much paſſes through every ſection of the river, for which one experiment accurately made, is ſufficient.

When it is known what quantity of water a river will furniſh, the next thing to be conſidered is, to what height it can conveniently be raiſed. In low flat countries, the higheſt head that can be obtained, is commonly from 4 to 7 or 8 feet: but in ſuch ſituations, there is for the moſt part a plentiful ſupply of water; and one of the greateſt inconveniencies there, is, that the rivers are very ſubject to be flooded; by which the back water is raiſed upon the wheels of the mill, and frequently obſtructs them; and in winter and rainy ſeaſons, the mills are ſometimes totally ſtopped thereby for many weeks together: for the floods in theſe

rivers

rivers abate ſlowly, becauſe the water in them has a ſlow current.

In hilly countries, the mills are ſupplied with water from ſprings or brooks, with which they could do but little work, but that the water there can be raiſed to a high head, to 12, 14, or 16 feet, and ſometimes higher; and they are not obſtructed by back-water. The principal inconveniency in them is, that they cannot work conſtantly in dry weather, but muſt ſtand ſtill part of the day, till the water is penned up to a head; and ſometimes they have not enough to keep them going for a great while.

Though theſe defects cannot be wholly cured, either in high or low ſituations, yet they may in ſome meaſure be helped, by a better conſtruction of the water-wheels and bottomwork than they commonly have, as will hereafter be ſhewn.

When the ſtream of water that drives a mill paſſes under the wheels, they are called underſhot or groundſhot-wheels.

If

If the water is conveyed to the top of the wheel, and falls upon it on the further ſide, it is called an overſhot-wheel. And if the water falls upon the wheel on the inſide, near to, or a little above the center, it is called a breaſtſhot-wheel.

In order to give a clear idea of the effect of water, I ſhall firſt deſcribe an underſhot corn-mill, as I meaſured it, together with the owner of the mill; a very ingenious perſon, well ſkilled in ſuch works.

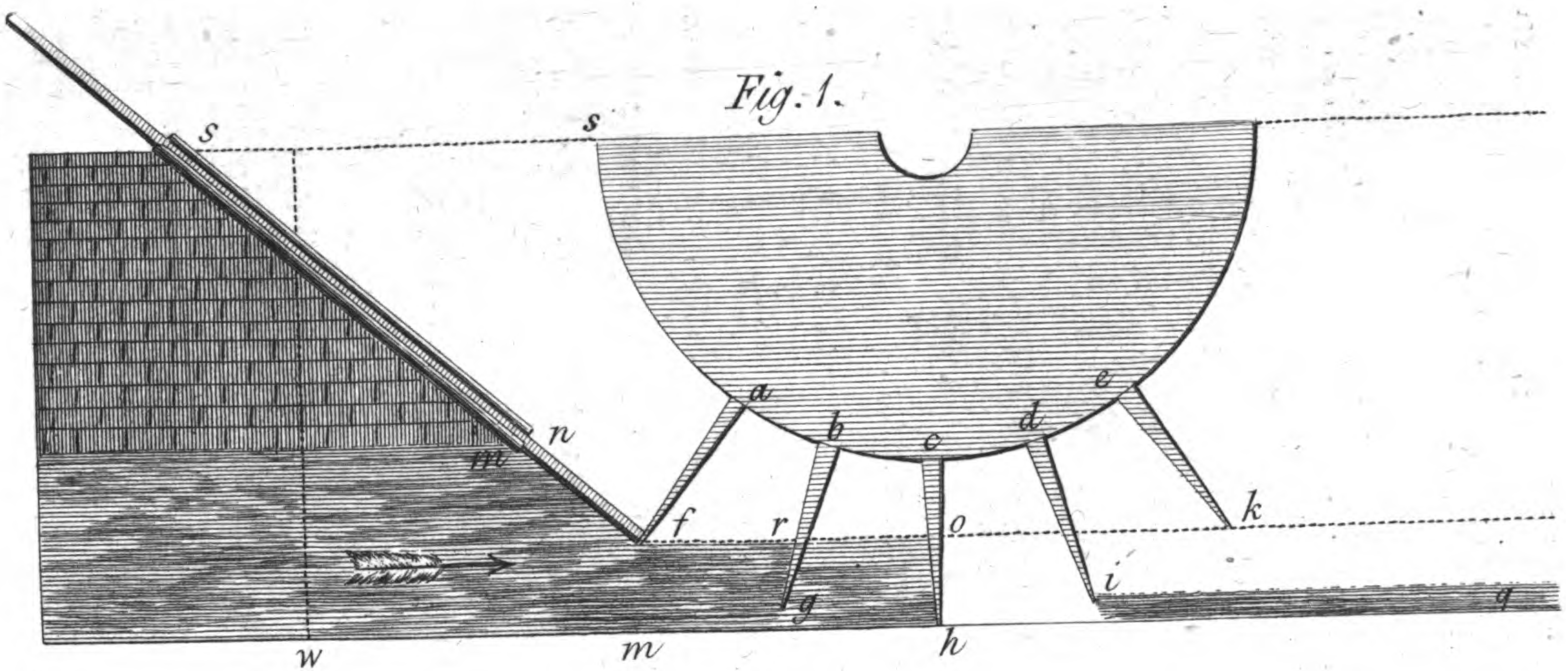
This mill has three thoroughs, one for the water to paſs under a wheel in the weſt thorough; another with a wheel on the eaſt ſide, and a waſte thorough between theſe, to carry off the water, when one or both of the wheels were not at work. The thoroughs are all nearly of the ſame width, and carried out to the ſame length, viz. 20 feet from the center of the wheels. Theſe thoroughs are not quite level at bottom, but decline $8\frac{1}{2}$ inches, from the center of the wheels to the

the further end of the thoroughs; the intention whereof is to carry the water off quick from the wheels, and prevent the back water from rising upon and obstructing them; and to prevent this the more effectually, the thoroughs are carried out to such a length: for when the thoroughs are short, the back-water comes up almost to the wheels, and very much obstructs their working: but the back-water being driven out to the further end of the long thoroughs, it cannot come up to the wheels, nor are they at all or very little obstructed by it, because the pressure of it is at the tail of the thorough, 20 feet distant from the wheels; for which reason it is the best way to make the thoroughs still longer, and to extend them to 25 or 30 feet below the wheels.

Undershot mills cannot be built so as to be wholly free from back-water, as the overshot may; because the undershot-mills are commonly erected in low flat countries,

countries, where it is difficult to obtain a good head of water, which in ſuch ſituations would be lowered as much as the bottom work of the mill was raiſed higher than common. And as the height of the head water is a principal conſideration, thoſe who erect mills in ſuch low ſituations, are obliged to ſubmit to the inconveniency of ſome back water. For ſuppoſe the water in a river can be raiſed 6 feet above the common ſurface; when it has rained for ſome time, the water in the river riſes every where; and if that riſe is a foot above its ordinary height, there will be in the thoroughs a foot of back-water, though before there was none. If the head-water could be alſo raiſed a foot higher, or to ſeven feet above the common ſurface, this would ballance the riſe of the back-water, as the riſe at the head would cauſe the water to iſſue through the penſtock with a greater velocity than it did before, and by that means the tail or back-water would be driven out of the

Fig. 1.



the thoroughs. But this cannot be done; the head-water muſt not be raiſed higher than 6 feet, to which the mill was at firſt adopted; but all above that height muſt be drawn off waſte, through ſluices placed in the bank above the mill, otherwiſe it would overflow the banks there, and run into the mill; and alſo overflow the neighbouring lands.

Plate III. fig. 1. *S W* is the head of water of this mill. *S S*, is the ſurface of water when at full head, and *S W* the depth or height, 6 feet. *S m* the penſtock, which ſtands oblique to the wheel, *a, b, c, d*, at an angle of 45 degrees from the perpendicular. This is a greater inclination of the penſtock than is common in ground ſhot mills, and was made ſo here, that the aperture in the penſtock might ſtand near to the float-boards, and cauſe the iſſuing water to ſtrike upon them with the greater impulſe.

S n f is the gate of the penſtock, which ſhuts down to the bottom *m h*, when the mill

mill is not at work; and when it is at work the gate is drawn up towards *f*, by which a paſſage is made for the water to iſſue through the aperture *f m*, which ſtriking upon the float-boards, as at *c h*, turns the water-wheel *a b c d e*. To ſhew this the more plainly, the float-boards are repreſented here deeper from *c* to *h*, than their juſt proportion.

The two water-wheels have each 24 float-boards, faſtened perpendicularly to the outward ring or ſole of the wheel, *a b c d e*. It is difficult to determine what number of float-boards are the moſt proper; and at what diſtance they ſhould be placed upon the wheels, to receive the impulſe of the water to the greateſt advantage.

If the gate of the penſtock, *S n f*, when the water is at a common head, is drawn up to *f*, and the aperture, *f m*, is then 6 inches deep for the water to paſs, and the floats are twice the depth of the aperture, or 12 inches, as the floats *a f*, *c h*, and *e k*, and placed upon the wheel at ſuch a diſtance, that the extremity of the foremoſt float-board, *e k*, when it riſes 6 inches perpendicular ſhall be at *k*, entirely clear of the current in the thorough; the following float *a*, *f*, will then juſt enter the ſaid current at *f*, and the middle float, *c h*, will receive the impulſe of the whole current, without being retarded by either of the two other floats. But by this diſpoſition, when the floats arrive to *b g*, and *d i*, ſome of the water will eſcape under the floats at *g* and *i*, as *i q*, and be waſted, becauſe it makes no impulſe on the floats, while in that poſition. On the other hand, if the floats are placed near together, the iſſuing ſtream cannot ſtrike fully againſt the middle float; and the current will be obſtructed by the foremoſt float, while it is riſing. A medium number, therefore, ſhould be choſen, which ſeems to have been nearly obſerved in the floats of theſe wheels, as this mill does as much work as moſt others, that have wheels

wheels of the ſame dimenſions, and the ſame head of water.

	feet.	in.
The diameter of the weſt wheel is	11	2
The depth of the floats,	0	10
Diameter, including the float-boards,	12	0
The diameter of the eaſt wheel is	10	10
Depth of the floats ——	0	10
Total diameter of this wheel, the floats included, is —— ——	11	8
The float-boards of both wheels are of the ſame length, viz. ——	3	2

The weſt wheel, with one part of the tackle, drives a pair of French mill-ſtones, for grinding wheat; and with the other part drives two bolting mills, to dreſs the flour.

The eaſt water-wheel drives a pair of French mill-ſtones, for grinding wheat; and one pair of Cullen or Peak mill-ſtones, to grind barley for hog-meat.

The full head of water that this mill can pen up to, is 6 feet. With this head, or an inch or two lower, the weſt

wheel

wheel grinds 5 bushels of wheat an hour, when the gate of the penstock is drawn up $6\frac{1}{2}$ or 7 inches; and at the same time works the two bolting mills, and dresses the flour. The bolting-mills are light, and do not require much force of water to drive them. When the water is kept constantly to the full head of 6 feet, the west wheel will grind 5 bushels of wheat an hour, when the gate of the penstock is drawn up only $5\frac{1}{2}$ inches; for there is some difference in the manner of grinding. A person who occupied this mill, some short time before the above mensuration, kept up a good head of water, and when the mill was at work, drew up the gate of the penstock 9 inches, which made the mill go so fast that the flour was heated and damaged. In general, this mill, with a full head, and the gate drawn up about 6 inches, will grind 5 bushels of wheat an hour, and dress the flour at the same time.

It was formerly the cuſtom, at the diſtance of 40 miles or more from London, to uſe Cullen millſtones, with which this mill would grind 8 buſhels of wheat an hour, without dreſſing the flour; which was not done than in the country. It was then ground only into meal, and the meal ſent to London, and dreſſed there. A mill for grinding wheat, if worked every day, ſhould have two pair of French millſtones, one pair to work, while the other is dreſſing and cooling, which is done about once a week.

In order to calculate the quantity of water expended in driving an underſhot-mill, it has been ſuppoſed, that the ſtream iſſuing through the aperture in the penſtock, entirely fills the aperture during the time of its running; and that it iſſues with the ſame velocity that a body acquires by falling in vacuo from the the ſame height that the center of the aperture is from the ſurface of the water above it.

It has been found by experiment, that a body in vacuo, accelerated by gravity, falls 16,0913 feet, or nearly 16 feet and 1 inch per ſecond; but will not in that time deſcend ſo far in air, being in ſome degree retarded by the reſiſtance of the air; in which its fall may, in even numbers, be reckoned at 16 feet per ſecond.

The velocity of water iſſuing through equal vertical holes, is in a ſubduplicate ratio of the height of the water above the center of the holes, viz. through holes at four times any depth, the velocity will be double to that through equal holes of that depth below the ſurface of the water. Thus through a hole at 16 feet deep, the velocity is double of that through a hole of 4 feet deep.

The velocity of water through an inch ſquare vertical hole, the center of which is two feet under a ſurface or head of water, kept conſtantly to that height above the center of the hole, ought to be nearly 11,34 feet per ſecond. And if the hole is, during that time, quite filled, the quantity expended will be the ſame, as if it was a ſolid body of ice, having a baſe an inch ſquare, and 11,34 feet in length, containing 136,08 cubic inches. But Dr. Deſaguliers found, by repeated trials, that an inch ſquare hole, at two feet under the ſurface, yielded but 5,06 tons an hour; which multiplied by 35,68, the cubic feet in a ton of water, is 180,5408 cubic feet an hour, which is 86,6592 cubic inches, or, 7,2216 feet in length per ſecond, that paſſed through this ſquare hole, by the experiment; but according to the rule of falling bodies, it ought to have yielded 11,34 feet per ſecond.

Alſo by Marriotte's experiments, a round hole of 3 lines diameter, the center of which was 13 Paris feet below the ſurface of the water, gave 14 Paris pints in a minute, whereof 35 made a cubic foot, Paris meaſure. See his Hydroſtatics, p. 167.

A Paris foot is to the English foot as 1068 to 1000, and therefore 13 Paris feet are equal to 13,884 English feet; and by the rule, the velocity of the water issuing from a hole at this depth under the surface is $\sqrt{13,884 \times 64,2882}$, or 29,876 English feet per second. But, as above there issued through this hole a cylinder of water of 3 lines in diameter; and 19,54908 Paris feet in length, in a second, which is 20,87841 English feet in length in a second, by experiment, instead of 29,876 English feet per second, which this hole should have given by the rule.

The first of these experiments gives a little less, and the second gives a little more than $\frac{2}{3}$ of the quantity determined by the rule of falling bodies. We may, therefore, take the medium of these two, as very near the quantity that issues in a second through small orifices; and that it is $\frac{2}{3}$ of what they should give by the rule.

It is a material enquiry, from what caufe it happens, that the real quantity given by fuch fmall orifices, falls fo much fhort of what they ought to give by the rule; a circumftance not taken notice of by thofe who have tried fuch experiments, but who in general fuppofe that the quantity given correfponds with the rule; or do not affign the caufe why it is otherwife.

The deficiency muft arife either from the velocity, or the quantity, falling fhort of the rule. That the velocity correfponds nearly with the rule, appears from jets of a moderate height, which when well executed, rife very near as high as they ought to do by the rule. And likewife becaufe the quantity given by holes of equal dimenfions, is nearly as the fquare roots of the heights of the water above them, which alfo correfponds with the rule.

And that the deficiency is in the quantity, and not in the velocity, appears ftill more

more clearly from an experiment related by Mr. Clare, in his Motion of Fluids, p. 89. " An experiment, ſays he, was accurately made by Dr. Deſaguliers, of the running of water horizontally, through a hole $\frac{5}{8}$ of an inch in diameter, the center whereof was juſt 4 feet below the ſurface of the water, of a veſſel kept always full. This vein of water ſo contracted itſelf, that at half an inch diſtance from the hole, that is where it ſeemed thinneſt, it all ran through a hole of half an inch diameter, made in a tin plate. By afterwards weighing the whole body of the water produced, and reducing it to a cylinder of half an inch diameter, or ſomething under, it appeared, that the velocity of the water iſſuing, was the ſame as a drop of water would have acquired in falling the height of 4 feet in vacuo. In this caſe therefore, we are not to call the hole or aperture $\frac{5}{8}$ but $\frac{4}{8}$ of an inch in diameter; and that we may always conſider as a hole without friction, with which the theory will ſufficiently correſ-pond."

It is alſo obſervable, that water iſſuing through a ſmall hole, does not run in a full body, equal in dimenſions to the area of the hole, as a body of ice would paſs, that exactly filled the hole. But the water iſſues with a circular or twiſting motion through ſmall holes, and ſome-what ſimilar in larger; and by that means they do not give the full quantity that might otherwiſe be expected, if they ran with a full ſtream equal to the hole. It was for this reaſon, and partly from the friction of the water againſt the ſides of the hole, that in the above experiment made by Dr. Deſaguliers, the quantity was ſo much ſhort of the rule.

The areas of circular holes are to each other as the ſquares of their diameters; as in the preſent caſe, the diameter of the hole in the veſſel being 5, the area is 25, which is the quantity it ſhould have gi-ven; and the diameter of the hole in the

tin

tin plate being 4, the area is 16, which is the quantity it did give; that is, the quantity from the veſſel was about $\frac{2}{3}$ of what it ought to have given, agreeable to the above experiments; and the deficiency was in the quantity, and not in the velocity. The cauſe of this great deficiency in ſmall holes, is principally from friction, and the twiſting motion.

In large apertures, the friction is not proportionally ſo great, as in the ſmall; but in theſe the deficiency is alſo very great from other cauſes. The large body of water neceſſary to ſupply ſuch apertures, muſt come from ſome diſtance all round them, and meeting at the aperture in all directions, cauſes an irregular and inteſtine motion there, which obſtructs the free paſſage of the water, ſo that the deficiency is often as great as through the ſmall holes.

That we may apply this to the above underſhot-mill, whereof the head is 6 feet high, the gate being drawn up 6 inches,

inches, and the aperture 38 inches wide, the area through which the water paſſes to the floats, is $38 \times 6 = 228$ ſquare inches, or 1,58333 ſquare foot. And as the center of that aperture is 5 feet 9 inches, or 5,75 feet under the ſurface, the velocity of the water is 19,22647 feet per ſecond by the rule, which multiplied by the area of the aperture 1,58333 gives 30,44127 cubic feet for the quantity of water expended per ſecond; but, as we have ſhewn above, the real quantity is but about $\frac{2}{3}$ of this, viz. only 20,29418 cubic feet per ſecond, which is 2038,6453 tons an hour, to grind and dreſs 5 buſhels of wheat.

This is a much greater quantity of water than is neceſſary for overſhot and breaſtſhot-mills, to grind the ſame proportion of wheat; and if they required as much water, very few mills would be erected. But underſhot-mills being built upon rivers, have a large ſupply of water, through the greateſt part of the year.

This

This mill, which is upon a ſmall river, has water enough to work conſtantly about half the year, and during that time grinds about 20 loads of wheat per week, 40 buſhels to the load, 9 gallon meaſure: but the other half of the year, can grind and dreſs but about half that quantity; as there is not water enough then to keep the mill conſtantly employed; but all the gates muſt be frequently ſhut down, till the water riſes to a full head.

This inconveniency would wholly, or in a great meaſure, be removed by a different conſtruction of the water-wheels, which if made 18 or 20 feet diameter, and the floats 6 feet wide, this mill might be worked conſtantly throughout the year, grind and dreſs 5 buſhels an hour, with the quantity that is now reckoned ſhort water; and do more work with a full ſupply of it, than can be done at preſent. But the improvement would be ſtill greater, if this was made a breaſtſhot-mill, as will appear hereafter.

In order to determine the force of water upon the wheels of a mill, it is neceſſary to know their velocity: for that purpoſe I meaſured the velocity of the weſt wheel of this mill, by a half ſecond pendulum, and found, by repeated trials, that, when at work with a full head, it revolved full 18 times in 60 ſeconds; and I have found that the wheels of ſome other corn-mills of nearly the ſame conſtruction and diameter, revolved at the ſame rate when in full work, with an equal head of water.

The middle of the aperture being 3 inches, the greateſt impulſe of the iſſuing water is at that height upon the floats, which being deducted from 12 feet, there remains 11,75 feet for the diameter of the weſt wheel, and the circumference at that diameter is 36,9285 feet, which as above revolves 18 times in 60 ſeconds, or 11,0786 feet per ſecond, for the velocity of the wheel, which is above half the velocity of the water, as it iſſues from the aperture in the penſtock.

Monſieur Parent's *maximum* is, that an underſhot-wheel can do the moſt work when its velocity is equal to one third of the velocity of the water that drives it. This would be nearly true, if the aperture did give the full quantity of water, with the velocity of bodies falling in vacuo. But, as it has been ſhewn above, that though the water iſſues through the penſtock with that velocity nearly, yet as the iſſuing ſtream fills but $\frac{2}{3}$ of the aperture, it can have but $\frac{2}{3}$ of the effect of the full quantity; and therefore that an underſhot-wheel can do the moſt work when the velocity of the wheel is equal to one third of the velocity of the iſſuing water, according to the rules of falling bodies, and two thirds of the quantity of water that the aperture would give, if the iſſuing water quite filled the aperture.

Computing, therefore, the effect of water through ſuch apertures, without regarding

regarding the quantity they give, Mr. Parent's rule will be right, that an undershot-wheel can do the most work when its velocity is one third of the velocity of the water that drives it.

But if we take the quantity and velocity both into the account, the water in that case has the greatest effect when it moves with only twice the velocity of the wheel. Agreeable to this, Marriotte says, p. 136, that the wheels of the mills upon the river Seine, at Paris, have at their circumference but half the velocity of the running water that strikes against them. And that the same proportion is observed in the wheel of the pump of the Samaritain. For here the impulse is made by the full quantity of water; every foot square of the float-boards, is impelled by a body of water of the same dimensions; whereas the body of water issuing through a penstock, upon the floats of an undershot-wheel, is really

really but $\frac{2}{3}$ of the dimenſions of the aperture, as we have ſhewn above.

There is ſuch a large ſupply of water in rivers, that the mills, as they are uſually conſtructed, cannot make uſe of it all, in a full water, and much of it is then drawn waſte through the waſte thorough of the mill, and through ſluices placed for that purpoſe in the banks above the mill. But in floods, all theſe are not ſufficient; the water riſes every where in the river, and the wheels are ſtopped by the back-water.

This is a great abatement in the value of mills ſo ſituated: for ſometimes they cannot work for weeks, and even months, together. Any cheap method, therefore, that can be contrived to keep theſe mills at work in a full water, and in floods, muſt be acceptable to the owners and occupiers of ſuch mills.

The float-boards of ſuch mills are commonly but about a foot deep, and for that reaſon cannot drive out two or three feet deep of back-water, but by drawing the

gate

gate of the penſtock higher than common, and enlarging the aperture for the paſſage of the water, that may be done, provided the float-boards of the wheels are adapted to the aperture. This may be done by making ſliding float-boards, to be drawn out or put in occaſionally. The ſole of the wheel ſhould be placed nearer the center; and in floods, the float-boards ſhould be drawn all out alternately. As ſuppoſe the wheel has 24 floats in a common water, the boards of 12 of them are to be taken out in time of floods. It is not neceſſary that all the boards of theſe 12 remaining floats ſhould be moveable, thoſe next the circumference of the wheel, of about a foot deep, may continued fixed, and if boards are made to ſlide on about two feet more, may be ſufficient.

This method is yet very uncommon, though a great improvement; but as ſome perſons may doubt the effect of it, and whether a back-water of two or three

feet

feet can be driven out in this manner, I ſhall ſhew the force of the head-water when this alteration is made; firſt premiſing, that the floods in the Thames ſeldom riſe much higher than two feet above the level of a common full water: but in rapid rivers, where the floods riſe to a great height, they are ſeldom of ſuch long continuance as to render ſuch precautions neceſſary, if the mills are erected in a proper ſituation.

Suppoſe the back-water is two feet deep upon the wheel, and the floats are alſo made of that depth by additional or ſliding-boards. Draw up the gate of the penſtock two feet; the middle of the aperture will then be 5 feet below the ſurface or the head-water, the quantity expended will be 6,41602 cubic feet per ſecond, iſſuing through the penſtock with a velocity of 17,92877 feet per ſecond; but turns the wheel with only about half that velocity, or 8,96438 per ſecond; and being diſcharged at that rate from the wheel, has a velocity more than ſufficient to drive out the back-water.

Again, if the back-water is 3 feet deep, the floats made ſuitable, and the gate drawn up 3 feet, the center of the aperture will then be 4½ feet below the ſurface of the head-water. The quantity diſcharged is 8,9722 cubic feet per ſecond, iſſuing at the aperture with a velocity of 17 feet per ſecond, and half that velocity, viz. 8½ feet at the wheel and thorough.

Hence it appears, that by drawing up the gate 2, 3, or more feet, there is water iſſuing from the aperture with a ſufficient velocity to drive out the back-water, and the ſame at intermediate diſtances, if the floats are made of a proper depth, by the ſliding-boards: by which the motion of the millſtones are likewiſe regulated: as it may alſo, where they go too faſt, by ſetting to work another pair of millſtones, or by drawing off ſome of the head-water through the waſte-gates in the banks above the mill.

Over-

Overſhot mills are very different from thoſe we have been treating of. They are not ſupplied with near ſo much water as the underſhot-mills, but that deficiency is in ſome meaſure compenſated by wheels of a larger diameter; by their having buckets to the wheels, which retain the water through part of their revolution, and give them an impulſe both by its weight and velocity; and alſo that they are not obſtructed by back-water, if erected in a proper manner.

This circumſtance is not always duly attended to, in building theſe mills; for back-water is a greater obſtruction to them than to the underſhot; and cannot be drove out by their head-water, as it may in the underſhot.

To explain this it is to be obſerved, that water falls on the inſide of the wheel of an underſhot-mill, and it revolves in the direction *a b c d e*, Fig. I. but the water falls on the outſide of an overſhot wheel, which cauſes it to revolve in a contrary direction; by which means it drives the back-water up towards the head, where it is continually pressing upon the buckets, and obstructing the revolution of the wheel. For this reason the mills should be built high enough to avoid any back-water, and may be easily done in their first construction; the high, or quick declining ground, upon which overshot-mills are erected, generally admitting of the head-water to be raised to such a height, that raising the bottom work above the level of the back-water, will not make much difference in the force of the water that falls upon the wheel; or may be compensated by larger buckets, or a little more breadth in the wheels.

Overshot-mills require a great deal less water than the undershot to do the same work. Mr. Beighton describes an overshot-mill at Nuneaton, in Warwickshire, as a good one. The water-wheel is 16 feet in diameter, and has 30 buckets,

$17\frac{1}{2}$ inches wide, 19 inches deep, and 4 broad at the bottom, and their diſtances from each other at top, is the ſame as the width, viz. $17\frac{1}{2}$ inches.

The water is raiſed $23\frac{1}{2}$ feet high above the bottom work of the mill; and the head-water is $7\frac{1}{2}$ feet above the top of the wheel. At the bottom of this head-water there is a trough or trunk, 12 inches ſquare within. And in the trough there is a penſtock, with a gate or draw-board, $10\frac{1}{2}$ inches broad and 12 inches high; and when the mill is at work this gate is drawn up about 2 inches high: ſo that the aperture is $10\frac{1}{2} \times 2$ inches, or 21 ſquare inches area. The bottom of the trunk is level with the top of the wheel, where the water is delivered into the buckets, about 6 feet from the pen-ſtock. The water-wheel makes 8 revolutions in a minute. It has a face-wheel fixed upon the ſame ſhaft or axis, with 48 cogs; and this turns the lanthorn or trundle that is fixed to the upper mill-

 ſtone

ſtone. The trundle has 9 rounds. So that for every revolution of the water-wheel, the mill-ſtone goes round 5,33 times; and conſequently 42,4 in a minute.

This mill, Mr. Beighton ſays, will grind 30 buſhels of corn in 12 hours, the buſhel being $\frac{1}{32}$ part more than the Wincheſter. There are another pair of ſmaller mill-ſtones, that may be worked by the ſame water-wheel. Theſe, he ſays, are uſed for grinding wheat for fine flour; by which it ſeems the larger pair are not for that uſe, but for grinding other corn; and he ſays nothing of bolting or dreſſing the flour; bolting-mills being of later invention, except near London.

The ſurface of the head-water being 7,5 feet above the top of the wheel, the velocity of it is 21,9581 feet per ſecond, which multiplied by 21 ſquare inches, the area of the aperture, produces 3,2022 cubic feet per ſecond iſſuing through the penſtock by the rule, but by experiment only

only $\frac{2}{3}$ of that quantity, viz. 2,1348 cubic feet of water per ſecond, to drive this mill.

The above deſcribed underſhot-mill, would grind 8 buſhels of wheat an hour, 9 gallon meaſure, with Cullen or Peak-ſtones, which is 288 quarts. The Nun-eaton mill ground $2\frac{1}{2}$ buſhels, or $82\frac{1}{2}$ quarts an hour, probably in the ſame manner, and with the ſame kind of mill-ſtones. The firſt required 20,2941 cubic feet of water per ſecond, and in an hour 73058,76 cubic feet to grind 288 quarts; and the latter required 2,1348 cubic feet, per ſecond, and in an hour 7685,28 cubic feet, to grind $82\frac{1}{2}$ quarts. But the Nun-eaton-mill, to grind the ſame quantity as the underſhot, viz. 288 quarts, would require 26829,528 cubic feet an hour. The underſhot-mill therefore requires almoſt three times the quantity of water, that this overſhot-mill does, to perform the ſame work, in the ſame time.

The difproportion would be ftill greater if the water employed to drive the over-fhot, was applied in the manner as in a fweep or breaftfhot-mill, and with as high a head: for even in the low heads the advantage of the breaftfhot is confiderable. I know a corn-mill that has two water wheels, and a low head of water, not quite five feet high: both wheels were formerly ground fhot; but fome years ago the occupier had one of the wheels altered to a breaftfhot. With this wheel before it was altered, the mill ground fcarce 4 bufhels of wheat an hour; and fince the alteration it grinds 5 bufhels an hour. No alteration was made in the diameter of the wheel; only inftead of the water paffing under the wheel, as it did before in the fame manner as in other groundfhot-mills, it is now brought to the top of the wheel, in a trough four feet wide and about two feet in the water. There is a notch or hole acrofs the bottom

of

of the trough, the whole breadth of it, through which the water falls perpendicularly upon the floats, a little below the center of the wheel. This wheel requires now much leſs water than before, though it does more work.

A groundſhot paper-mill, that ſome years ſince had not near water enough in dry weather, and the owner was then obliged to ſhut down the gates great part of the day, in order to raiſe a head of water to work the reſt of the day, this being then a groundſhot-mill; but the owner having altered it to a ſweep or breaſtſhot-mill, there is now water enough, not only to work the mill conſtantly, but commonly more than is neceſſary: ſo that ſome water is drawn off waſte every day. I ſaw this mill in full work, and at the ſame time ſome water drawn waſte, in one of the drieſt ſeaſons that I remember: and as this is one of the principal modern improvements in the water-wheels of mills, I

ſhall

ſhall give a more particular deſcription of it; agreeable to the dimenſions of the wheels and bottom work of a paper-mill of that conſtruction, which I meaſured.

Pl. III. fig. 2. is a tranſverſe ſection of the two water-wheels and breaſt-work, &c. of a paper-mill. The breaſt-work is of brick, built in a circular ſweep, *p*, *n*, *o*. B, is the upper wheel, 8 feet 10 inches long, and 7 feet 5 inches in diamete, excluſive of the floats. The floats are 7 inches high above the wheel, 12 inches diſtant at top, and 25 in number. They are made feather-edged, being one inch thick at top, and $2\frac{3}{4}$ inches thick next the wheel.

This mill has two water-wheels of the following dimenſions.

	feet.	in.
The length of the upper wheel B,	8	10
Length of this wheel and floats, excluſive of the rings at the ends of it,	8	3
Diameter of the wheel, including the floats,	8	0
Depth of the float boards above the barrel,	0	7

The ſtreight ſides of the floats, upon which the water falls, ſtands perpendicular to tne barrel.

The

	feet.	in.
The length of the lower wheel C, including the rings at the end, ——	10	4
Diameter of this wheel, including the floats,	7	2
This wheel has 22 float-boards, each in length	9	9

The float-boards are 12 inches diſtant at their tops, and are 7 inches high above the barrel. They are feather edged, and of the ſame thickneſs as thoſe of the other wheel.

Both wheels are barrels, made of boards one inch thick.

The ſhafts of each wheel are 14 inches ſquare; and the iron gudgeons in the ends of the ſhafts, upon which the wheels turn, are 3 inches in diameter, and extend 3 inches beyond the ends of the ſhafts.

The breaſt-work, A, is of brick, with a circular ſweep *p*, *n*, *o*, built ſo as to fit exactly the floats of the wheel, B, which almoſt touch the brick-work of the breaſt-work, and brick pavement below, that no water may eſcape there, and be waſted. The lower wheel C, is incloſed

by

by a ſweep made of boards, about an inch thick, at *r s t*, which the floats almoſt touch, to prevent any water being waſted from the wheel.

The thorough is paved with brick, and widens from the lower wheel, to 12 feet, to give the water a free vent; and the bottom has a drip or fall, from thence to the lower end of the thorough, of 6 inches: when the water is all ſhut in at head, the pavement is dry. And when the head-water is at full height, it is nearly 8 feet and 1 inch above the ſurface of the back-water. It is neceſſary that ſuch breaſtſhot-wheels, ſhould ſtand as clear as poſſible of back-water; which if it was of any conſiderable depth, could not be driven out of the thoroughs, by the thin ſheet of water that works theſe wheels; as it may in underſhot-mills.

The water to drive theſe two wheels, comes from a ſmall branch of a river, in the bank of which there are two ſluices, each four feet wide, the gates whereof are com-

commonly drawn up about a foot, to keep both wheels going.

The water is conveyed to the wheels in a large trough, the top whereof is about an inch higher than the tops of the wheels; and when they are at work, the trough is kept quite or very near full of water, which is then 26 inches deep next the wheels, the trough there being of that depth. The ſurface of the water in the trough, when quite full, is 8 feet and one inch higher than the pavement of the thorough.

In the bottom of the trough are cut two long notches or holes, one over each wheel, and of the length of the float-boards. The notch to the upper-wheel is 8 feet 3 inches long, and 6 inches wide; and the notch at the lower wheel is 9 feet and 9 inches long, and 5 inches wide. There are ſliding ſhutters to each notch, which are ſhut cloſe or open by levers or handles, by which theſe notches or openings are made wider or narrower at pleaſure,

pleaſure, and more or leſs water is thereby let down upon the floats, as may be found neceſſary. It is very rarely, if ever, neceſſary to draw the ſhutters quite back, and open a paſſage for the water through all the hole at once. The quantity of water neceſſary to turn the wheel being more or leſs, in proportion to the work to be done by it; it is commonly ſufficient to draw back the ſhutter, and open a paſſage for the water about 2 inches wide, ſometimes more.

The trough is 26 inches deep, and the bottom of it about 2 inches thick; and the water, after it has paſſed through the hole at the bottom of the trough, falls 18 inches before it touches the float-boards; the height of the ſurface of the water, therefore, above the firſt float-board it touches is about 3 feet and 8 inches, whereof it falls 18 inches in the air. It has not been determined by accurate experiments what proportion of the head ſhould be allowed to the depth in water, and to its fall from thence upon the float-boards in air. But as this mill performs well, it seems that the proportion allowed here, is nearly the best to produce the greatest effect.

The lower wheel is of the same height at top as the upper one, but does not go so low as the pavement by 10 inches, (being so much less in diameter than the upper one) by this means the water discharged from the upper wheel has a free passage under the lower one, without obstructing it. To compensate for the lower wheel being 10 inches less in diameter, it is made 18 inches longer than the upper one. The water when discharged from the upper wheel at *d*, runs from thence down the thorough, in a thin sheet to *y*, and from thence the water from both wheels unite, and proceed to *z z*.

It is found by experiment, that a hole in the bottom of a vessel gives more water, than an equal hole in the side of it, the surface of the water above both holes being

being of the ſame height. This is partly occaſioned by the change of the direction of the water, which falls, as it is naturally inclined to do, directly perpendicular through the hole at bottom; but in paſſing through the vertical hole it muſt alter its direction, and iſſue out horizontally. And hence the water in breaſt-ſhot-mills makes a greater impulſe upon the floats, than it does in the underſhot; and alſo has a greater effect, becauſe it acts upon the floats of the breaſtſhot both by its weight and impulſe, but acts upon thoſe of the underſhot by its impulſe only, its weight being wholly upon the bottom of the thorough.

When the water is 2 feet deep in the trough, it will iſſue through the notch or aperture at bottom with a velocity of 11,3347 feet per ſecond by the rule, but by experiment only $\frac{2}{3}$ of this, or 7,5564, feet per ſecond. And admitting that the hole at bottom is 2 inches wide, and the length of it for the upper wheel being 8 feet 3 inches, the area is 198 inches of water continually paſſing, which multiplied by the velocity, produces 10,39 cubic feet per ſecond, to drive this wheel.

If we compare the quantities of water neceſſary to work theſe mills, per ſecond,

	Cubic feet.
The underſhot requires per ſecond	20,2941
The overſhot Nuneaton mill	2,1348
The breaſtſhot	10,39

Much of the water that falls upon an overſhot-wheel, daſhes away on each ſide, and is waſted; for which reaſon the Nuneaton mill did ſo little work, grinding only 30 buſhels of corn in 12 hours, or $2\frac{1}{2}$ buſhels an hour. Whereas a breaſtſhot, where none is waſted, would do more work, with a wheel of the ſame diameter.

It appears here that the breaſtſhot wheel requires a great deal more water than the overſhot; but it is to be conſidered, that the water which drives the overſhot-wheel, ſtrikes upon the floats,

 with

with almoſt double the velocity that it does upon the floats of the breaſtſhot: and likewiſe that the diameter of the overſhot-wheel, is near twice the diameter of the breaſtſhot; both theſe make a great difference in the effect of the water upon thoſe wheels; much greater than is ballanced by the greater length of the floats of the breaſtſhot-wheel. Add to this, that the underſhot in the preſent compariſon does a great deal more work; and that the overſhot, to do as much work as the underſhot, requires about one third as much water.

When it was propoſed to bring the Cowley ſtream (one of the branches of the Uxbridge river) to London, for a ſupply of water to the inhabitants, Dr. Deſaguliers meaſured a ſection of it, under the bridge, and found the velocity of the ſtream there to be one foot per ſecond, and that through the ſection, there paſſed 60 cubic feet of water per ſecond. So that if this ſtream was raiſed to a head 6

feet

feet high, it would drive three underſhot wheels, ſuch as I have above deſcribed.

Mr. Labalye, in his account of Weſtminſter-bridge, ſays, that the river Thames is there nearly 1220 feet broad. That at common low water, (when not kept up by the tide, nor ſwelled by floods) in the ebb channel near the Surry ſhore, the water is about 8 feet deep, and in the flood channel, 6 feet deep near the Weſtminſter ſhore; and that upon the ſhoal between the two channels, the water is ſeldom more than 4 feet deep at a common low water. The medium of theſe is about 6 feet deep of water, in that part of the river.

Weſtminſter bridge has 13 arches, and the whole opening or water-way between theſe arches is 820 feet, through which the water all paſſes at the time of ebb. The fall of water, occaſioned by the piers, is then but $\frac{3}{10}$ of an inch, under the arches; and the velocity of the water at the ſurface, barely $2\frac{1}{4}$ feet per ſecond just above and below the bridge.

As the water at the bottom and ſides runs conſiderably ſlower than at the ſurface, and cannot be much accelerated by ſuch a ſmall fall as $\frac{3}{10}$ of an inch, the mean velocity of the river at that place, is probably not more than $1\frac{1}{2}$ foot per ſecond, at which rate the quantity of water that paſſes at ſuch times through Weſtminſter bridge, in $820 \times 6 \times 1\frac{1}{2} = 7380$ cubic feet per ſecond. So that if the river Thames, at a common water, was all raiſed to a head of 6 feet high above the the apertures, it would drive 369 ſuch underſhot-wheels as above deſcribed.

In the water-works at London bridge, the water-wheel under the arch next the city, is 20 feet diameter. It has 26 floats, each 14 feet long and 18 inches deep. The velocity is 11,4166 feet, and of the wheel 5,1666 feet per ſecond: ſo that the wheel moves with nearly half the velo-

velocity of the water, or as 1 to 2,2, agreeable to what we have ſhewn above, and that it ought to do, by the rule of the congreſs of bodies; and would be more nearly ſo, if the velocities could be meaſured exactly, which in ſuch experiments it is not eaſy to do; and in calculations upon this ſubject reſpecting mills, is not neceſſary.

By the foregoing directions may be known what quantity of water any river, brook, or ſtream will yield; for having taken the level of the place to which it is to be conducted, and what height can be obtained for the head of water; it may then be determined which is the moſt proper kind of mill to erect there, an underſhot or breaſtſhot, to do the moſt work. As to overſhot-wheels, it is not adviſable to erect them: for where there is a head ſufficient for an overſhot-wheel, a breaſtſhot one may be erected, which is preferable to an overſhot in ſeveral reſpects, and will do more work with the ſame quantity of water. We have ſeen, by the examples above mentioned, the advantage gained by lengthening the float-boards, as in the breaſtſhot-mills, though the diameter of the wheels is leſs than common; but where there is ſuch a fall, that the wheels may be alſo made of a large diameter, the advantage of breaſt-ſhot-wheels is greatly encreaſed beyond what is obtained in overſhot-mills.

The examples given above of the force of water, is in regard to corn mills, theſe being the moſt common and uſeful; but as the ſame is applicable to many other uſeful purpoſes, I ſhall next take notice in what manner the impulſe, force, or momentum of running water is to be determined generally, and however applied, to grinding corn, or performing any other work.

The impulſe or momentum of water, is in proportion to the product of the ſquare of the velocity multiplied by the area of the aperture. As in the deſcribed under-

underſhot mill, the velocity through the aperture was found to be 19,2264 feet per ſecond, the ſquare of which is 369,6534, to be multiplied by the area of the aperture, 1,5833 ſquare feet, but as we ſhewed that by experiment, only $\frac{2}{3}$ of the aperture is filled by the iſſuing water, viz. .6333, this multiplied by the ſquare of the velocity produces 234 cubic feet, at $62\frac{1}{2}$ pounds per cubic foot, is 130 hundred weight, for the force or impulſe of the water.

The force of this impulſe is not wholly ſpent upon grinding the corn, but a conſiderable part of it is loſt by friction of the gudgeons of the water-wheel, and of the cogs and other parts that touch and rub againſt each other. The friction is greateſt in ſuch machines where pullies, ropes, and ſcrews are employed; and in general, the friction in compound machines abates about $\frac{1}{3}$ of the power by which they are worked. Thus in the preſent caſe, the aperture of the penſtock of the underſhot-wheel being 6 inches, we are not to eſtimate, that the whole force of the 6 inches deep of water is exerted in grinding the corn, but that 2 inches, or one third of it, is exerted to overcome the friction of the wheel and other parts of the mill.

There is one great advantage in breaſtſhot-mills above the underſhot, that the bottom work of the latter is vaſtly more expenſive at their firſt erection, and afterwards keeping it in repair, than that of the breaſtſhot. This leads us to conſider the method of conſtructing ſuch bottom work, and to give ſome directions, from experience, of performing it in the beſt manner, that it ſhall not be ſubject to decay or damage for a very long courſe of years.

It is cuſtomary in many places, to conſtruct the bottom work of underſhot-mills of timber, a material very ſubject to decay in water-works, where it is ſometimes wet and ſometimes dry; and for this reaſon it is, that ſuch work, as alſo locks and ſluices of timber, ſeldom laſt longer than 20 or 30 years, and in that time muſt be entirely new done and re-built; which is a heavy expence upon the owners, and much reduces the value of ſuch eſtates that have a dependence upon water-works. Timber is alſo liable to wear in the run of water. But the circumſtance of the greateſt conſequence is, that when the bottom work is done with timber, as it is commonly performed, the weight or preſſure of the head of water is ſo great, eſpecially near the bottom, that if it finds the ſmalleſt paſſage, it will, by its conſtant preſſure, waſh and wear away the earth at that paſſage and force its way under the ſill (which is called blowing) till the bottom is ſo much torn away, that there is a neceſſity of taking it entirely up and rebuilding it. This happens ſometimes ſo ſuddenly, that the danger is ſcarcely perceivable, till the blowing is paſt remedy. I have known ſeveral inſtances of this kind, and one

one in particular, where the blowing, had it been perceived in time, might have been prevented or the bottom ſecured, for about 40 or 50 ſhillings, that coſt above 150l. to reſtore it.

This expence is frequently greater, but in none perhaps ſo great as in that memorable breach in the banks of the river Thames at Dagenham; where, by a neglect of repairing a ſluice in time, the river broke in upon the levels of Dagenham and Havering in Eſſex, and waſhed away above 100 acres of the ſolid land, to the depth in ſome places of above 30 and ſome 40 feet; and coſt an immenſe ſum to ſtop the breach; all which might have been ſaved, had the bottom of this ſluice been built with ſtone or brick, in the proper manner. But many ſluices in the banks of the Thames are ſtill built with timber; and it is not uncommon for ſundry breaches to happen there, in conſequence of their being ſo built; though none of them have been attended with ſo

very

very great damage and expence, as that at Dagenham. Yet, ſome time before that, there was one at Longreach, below Purfleet, which continued more than ſeven years before it was ſtopped.

To ſecure the bottom of mills, and other works in water, where that is raiſed and kept up above the common level, it is neceſſary to lay the foundation deep to prevent blowing. But in ſome ſituations the ſoil is ſpringy, or a quick-ſand, where it would be expenſive to keep out the water, ſo as to lay a deep foundation; and after all might prove inſecure, and not ſufficient to prevent the penetration of the water under it: for the preſſure of the water upon the bottom is very conſiderable.

As, for example, ſuppoſe the head is 6 feet high, every ſquare foot of the bottom ſuſtains a column of water 6 feet high, whoſe baſe being a foot ſquare, the column is 6 cubic feet, at $62\frac{1}{2}$ pounds per cubic foot, is 375 pounds, continually

preſſing

paſſing upon every foot ſquare of the bottom; wherein if it finds the ſmalleſt ſubtarraneous paſſage, the water will force through it, with a velocity of 19.64 feet per ſecond, which is more than ſufficient to carry away the earth all round this ſmall ſubterraneous paſſage, ſtill making it wider, till the bottom is blown, and muſt be taken up.

This weight and preſſure of the head-water, is only from the ſurface to the bottom ſill of the penſtock, and reaches no further, provided the ground there is a clay, or other ſtrong cloſe ſoil, through which the water cannot penetrate: but if the earth there is a ſand, gravel, or porous ſoil, the preſſure is continued through theſe pores, and the force of it ſtill encreaſes in proportion to the depth; and hence the great danger of blowing: for water preſſes not only downwards, but in all directions; for which reaſon, though the bottom and ſides ſhould be ſecured from leakage to the depth of a yard or

more,

more, the water will notwithſtanding penetrate deeper, and force its way up through the apron; or running all the way under, will force its way up at the lower end of it.

If the bottom of the thorough was not ſecured from the violence of the water iſſuing through the penſtock, it would quickly carry away the earth of the thorough near the upper end of it, to a great depth, and the head-water finding little reſiſtance, and penetrating under the ſill, the bottom would be blown in a very ſhort time: to prevent this, it is uſual to cover the bottom of the thorough there, with an apron or ſheeting of boards, and to drive ſhort piles acroſs the thorough at the lower end of the apron: this is ſome defence againſt the running-water, but it is only temporary. The continual current wears the apron in holes, and the head-water is found to force its way, not only through the apron, but frequently under the piles. And upon the whole,

whole, the bottom-work of theſe mills, ſluices, locks, dams, and other ſuch water-works, either from wearing by the running water, or blowing, are generally ſubject to decay in no long courſe of years.

The locks on the river Thames, are dams made acroſs it, to pen and keep up heads of water for the mills; an opening is left in the middle of the dam about 20 feet wide, for the veſſels navigated upon that river to paſs up and down, and after they are paſſed, the opening is ſhut with draw-boards to keep up the head of water, about ſix or ſeven feet high. To ſecure the bottom of theſe dams, rows of piles are drove acroſs the opening, and great quantities of large chalk-ſtones thrown in between the piles, ſloping from the head to the bottom of the river; which prevents the water from gulling the bottom cloſe to the head-water. But it falls upon the chalk, and runs with ſuch rapidity, that the ground below the chalk

is

is loosened and carried away, to a very considerable depth and distance, and a bank is thrown up below, by which the barges are frequently obstructed or stopped. The same thing would happen in the thoroughs of mills, if the bottoms of them near the head, were not covered and defended against the impetuosity of the water issuing through the penstock: the water would gull and drive away the earth to a great depth near the head, and then the head-water, by its weight or pressure, would soon force its way under the sill of the penstock, and blow up and destroy the bottom-work. For this reason it is absolutely necessary to secure the thorough, by aprons or some other means.

Could a head of water be kept up to the height of 6 feet, by a stone or brick-wall, laid 9 or 10 feet deep in the ground, the blowing might be prevented by such a wall, provided the earth was not carried away below the wall, by the water running through the opening of the pen-ſtock: or it might by the ſame means be prevented, where the head is a great deal higher, by making the wall of a proportionable depth in the ground. But in great depths, the building of ſuch a wall would not only be very expenſive, but in bad ground often impracticable.

To give an example of this, it may be here obſerved, that when it was determined to build a bridge acroſs the Thames at Weſtminſter, different methods were propoſed of laying the foundations of the piers in the bed or bottom of the river, of a ſufficient depth; whereof one was by means of batterdeaux or coffer dams; which Mr. Labelye, the engineer, deſcribes, and gives ſome reaſons why that method was impracticable in laying the foundations for the piers of that bridge, as follows.

" In building of the piers of bridges, ſluices, and other works in water, engineers and architects have often recourſe

to

to this method, viz. to inclofe the place intended for the foundation fo as to keep the ambient water from coming in, that it may be drained dry, and kept fo by pumping or other engines. Sometimes this inclofure is fingle, and fometimes double, with clay rammed between; fometimes the inclofures are made with piles only, driven clofe by one another; fometimes thefe piles are notched or dove-tailed one into another; fometimes the piles are grooved, and driven at a diftance, and boards let down between them. But let the inclofure or inclofures be made in any of the ways mentioned, or in any other way, the fole intent of this manner of proceeding, is only to keep the water from coming into the foundation, whenever it can be drained.

" The firft inconveniency attending this method is, that if the inclofure be not ftrong enough, or not fufficiently propped or braced in the infide, it will not be able to fupport the preffure of the external water, (eſpecially if it be water agitated by ſtormy winds) which, by breaking and burſting in, often deſtroys many lives, and entirely defeats the intentions of the projectors, that have not taken the neceſſary precautions, of which I could give a great many inſtances, ſome of which I have been an eyewitneſs to. But if this method had no other inconveniency, it could eaſily have been remedied in the execution of the intended bridge; England, and London eſpecially, abounding with excellent artificers of all kinds. But what would have rendered it entirely uſeleſs, or ineffectual, is the nature of the ground under the bed of the river Thames; which at the place where the bridge is, is every where a gravel, covered over on the Surry ſide with a ſort of loamy ſand; all which would ſuffer the water to ouze up (notwithſtanding the ſides of the batterdeaux or coffer-dams ſhould be perfectly tight) ſo faſt, eſpecially the gravel, as to put it out of the

power

power of any engine or engines, to drain the batterdeaux or coffer-dam. Indeed where the ground under the foundation is a ſtiff clay, or an earth of a ſufficient conſiſtency to hold water, batterdeaux or coffer-dams have been uſed with ſucceſs, though attended with an immenſe expence and trouble; and what I would have made uſe of, if I had not foreſeen, that it would have been in vain to attempt in this place to come at the bottom, and much more ſo, to reach ſeveral feet under the bed of the river, by any ſuch means. Thoſe that have ſeen (or have been concerned in) buildings erected in water, where the ground is a gravel, or a looſe clay, or a ſand, well know the inſuperable difficulties that would have ~~have~~ ariſen, if ſuch coffer-dams or batterdeaux had been attempted on the Thames, over againſt the Woolſtaple; where beſides the agitation of the water, occaſioned by the winds, the height of the water is perpetually increaſing or decreaſing, from

6 feet to about 23 feet, perpendicular height, above the ſurface of the bed; which two circumſtances would make it difficult, and very expenſive, to provide proper materials, and conſtruct a coffer-dam ſufficiently ſtrong, to reſiſt ſuch unequal preſſures, ſo as to keep out the ambient water.

"As to the ouzing in of the water through the pores and interſtices of the gravel, looſe clay, or ſand, it may eaſily be ſhewn, that if all the interſtices in the bottom of the foundation, of one of the piers, taken together, amount only to a hole of 6 inches ſquare, (which is a ſuppoſition much under the truth) and ſuppoſe the tide or height of the water above the foundation (as it is at a mean or average between the higheſt and loweſt) about 15 feet perpendicular, they would give above 770 tons per hour; which is more than 70 men could pump out, even ſuppoſing them to act always with the ſame ſtrength as they do at firſt, and to work

day

day and night without ceaſing; and more than 150 men, or 30 horſes could do, working as they commonly do.

" All that I ſhall add to this article is, that ſome of the perſons who propoſed or eſpouſed this method of making an incloſure round the intended pier, with dovetailed piles, and pretended to drain the water from within, might remember how fruitleſs was the attempt, or rather experiment, that was made of it in Hyde Park, not many years ago."

The force of the water riſing through the bed of the river appears further from the account given of it by Captain Perry, as he found it in laying down the apron of a ſluice that he made at Daggenham, before he began to ſtop the breach there; which he relates as follows, viz.

" When I came to dig down the place for my ſluice, notwithſtanding that I had, (when I came within about 6 feet of low water mark) driven down large dovetail piles, on each ſide and athwart the place, which I dug down for the moſt part upwards of 20 feet into the ground, by extraordinary engines for it, whereby to ſtop the courſe of the ſprings; which was done with large beams of timber, fixed acroſs from ſide to ſide, to prevent the ſliding in of the banks; yet I found the penetration of the water to have that force, underneath the dovetail piles, through the ſand and bad ground below the moor-logg, that the preſſure of the water at the depth which the ground was dug down, being near 22 feet difference of level upon the ſpring-tides, ſo ſwelled and lifted the moor-logg in the place for the ſluice, that it rounded up in the middle ſeveral inches, above the level to which it was dug; and the leakage began to take ſuch power, that I thought it not ſafe to open the ground any lower, and ſubmitted to fix the foundation or apron of the ſaid ſluice to a leſs depth than I would willingly have fixed the ſame to: and conſequently as I could

not

not place the ſluice to a greater depth, there could not, in the courſe of carrying up my works in the breach, be given ſo great an eaſe and vent to the water, by the way of that canal, as was neceſſary; the top of the apron being fixed only to within a foot of the depth of the ordinary low water mark in the Thames; which would have been of much more ſervice and ſatisfaction to me, could the ſame have been carried lower."

He then proceeds to relate, that as he could not lay the bottom of this ſluice any lower, he thought it adviſeable to put in another; which, ſays he, "I found equally difficult in fixing down that ſluice as the firſt; ſo that though I carried the foundation to a conſiderable depth beyond what was poſſible to have been done without the ſaid drift of dovetailed piles, yet found I durſt not venture the fixing of the apron of either of them below, or fully to the depth of low-water mark, left I should have been overpowered by springs and leakage."

It is not commonly necessary to dig down for the foundation of mills and other works, so low as in the above instances; yet where it is so, to the depth of about 10 or 12 feet, it is found expensive to lay the bottom dry, and keep it so, till the foundation is laid, and carried up to a proper height; and several pumps are frequently necessary for that purpose, to be worked by men or horses.

One of the best sort of pumps for this use, where there is room to work it, is that known by the name of Archimedes's screw; which consists of a round shaft, with grooves cut in it, in a helical or spiral line, from one end to the other: into this groove boards are fitted and fastened in, near the whole length of the shaft, the sides of these boards are to join close to one another, and to stand at an equal height above the shaft: upon the tops of

these

theſe boards are faſtened, narrow parallel boards all round, in form of a cylinder or barrel, ſecured with iron hoops. This pump is to be placed not upright, but declining at an angle about 45 degrees from the perpendicular. By turning, the lower end dipped in the water, it brings the water up to the top with very little friction, whence it is to be carried off in a trough.

Sometimes there is one ſpiral groove cut in the ſhaft, to receive the upright boards, which in that caſe forms but one ſpiral thread within the barrel; and this is the moſt common. But I have found that two ſuch threads, running parallel and equidiſtant, the length of the ſhaft, is better than one, and will throw out more water. But with three threads it will not diſcharge ſo much water as with one.

The largeſt of theſe pumps may be about 18 feet long. The more upright it is ſet, is raiſes the water higher, but in a ſmaller quantity. Laid much inclining, it raiſes more water but not ſo high, and requires the more ſtrength to turn it. Such a pump kept conſtantly going, will employ 16 horſes to turn it, four at a time; and is hard work for 12 horſes.

Smaller pumps of this ſort are worked by men, 5 or 6 at once, and frequently changed.

But there is another method of ſecuring ſuch works from blowing, cheaper, more eaſily performed, and not leſs effectual than the beſt walls, either of ſtone or brick, or to any required depth. This is by piling. A line of piles, under, or juſt above, the ſtill of the penſtock, may be driven to ſuch a depth, as to prevent blowing, even without an apron, and though the earth in the thorough was waſhed away as deep as the running-water from the penſtock could remove it. So that if this one line, under or cloſe to the ſill is ſecured, there is no danger of blowing. A circumſtance that none of the millwrights I have converſed with, nor others of more extenſive knowledge in water-works, ſeem to have fully conſidered. They lay aprons, or ſheetings of boards below the ſill, upon which the head of water is raiſed, and ſometimes aprons are laid above that ſill; and they drive ſhort piles at the lower end of the apron, and ſometimes alſo at the upper end of the ſheeting above the ſill; all with an intention to prevent the head-water from penetrating under it, but the line under or cloſe to the ſill, is left defenceleſs; and yet if the water penetrates there, all the other precautions will avail nothing.

Some have ſuppoſed that timber will decay in water, which if alternately wet and dry it certainly will. Or if laid in running-water, it will waſte and wear away; not from any natural decay of the timber, or corroſive quality in water; but on account of the motion, which occaſions

casions a friction and wearing of the timber by the sand and gravel mixed with the water: but to suppose that sound timber, laid at any depth in still water, will waste or decay, is a great mistake, and contrary to experience.

For it is found, that timber which has lain 50 years, or much longer, under water, is perfectly sound when taken up. And many heavy buildings in Holland and England, as London bridge, and others, built upon piles, have stood firm for ages; which is a proof that timber does not decay in water. The sense of the public, and of eminent engineers in this point, is evident from Westminster bridge, and more lately from Black Friers bridge; they being built upon gratings of fir timber, covered with fir planks.

In order to explain the method of constructing the bottom of a mill or other work in water, in such manner as will render it secure and lasting; let us suppose that the bottom work to be made, is

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for an undershot-mill, where the head of water is penned up to the height of 6 feet, above the common surface of the river that is to drive the water-wheels of the mill: that there are three thoroughs of 4 feet wide each, and two water-wheels, to be placed in the two outside thoroughs, and the waste thorough in between them.

First, drive a row of fir piles across the stream, 6 inches thick and dovetailed, as *pp*, Pl. III. fig. 3. These piles should be driven into the bed of the river 9 or 10 feet deep at least, viz. half as deep again in the ground, as the head-water is raised above it; this upon supposition that the bed of the river, is a firm close soil, which may be known by boring. But if it is a loose earth, or quicksand, it will be advisable to drive the piles deeper, viz. not less than 12 or 14 feet deep; or, which is still a better rule, till they reach and penetrate 3 or 4 feet into good close earth. The dovetail grooves in the sides of the piles will guide them

them in driving, ſo that they will join cloſe to each other throughout their whole length, and as they will be always wet, they will ſwell a little and continue ſo cloſe, that no water can penetrate through the joints. The air will be likewiſe excluded from them; and therefore, if they were ſound at firſt, they will continue ſo: for it is the changeable temperature of the air that cauſes timber, that is expoſed to it, to decay.

When the piles are driven to the depth intended, dig a trench cloſe to the row of piles of 3 feet deep or more, and 2 feet wide, in which the foundation is to be laid, of a brick-wall 2 feet thick. When this wall is brought almoſt as high as the bed of the river; ſaw off the tops of the piles in a ſtreight line, very true and even, as low as the bed or bottom of the river; then build the wall up as high as the tops of the piles, after which the wall is to be extended in breadth over them from *w* to *p*, and carried up to the propoſed height, battering

battering on the lower ſide *w*, *w*, to 18 inches or two bricks length. This wall, when carried up to the proper height, is to be one ſide of the mill.

If the ground is bad, upon which the wall is to be built, lay 2 long four-inch oak or fir planks at bottom, each 14 or 15 inches broad, and build the wall upon them, which will prevent the wall from ſettling; but if there is a quickſand at bottom, or ſo ſpringy that a trench cannot be dug for a foundation, it muſt either be cloſed piled all over, or double rows of piles driven acroſs the trench at ſmall diſtances from each other, and arches turned upon them, to ſupport the wall. Thick planks ſhould be laid upon the tops of the piles, and the wall built upon them.

The brick-work of the foundation ſhould be laid in tarris mortar, but no mortar of any ſort laid next the ſides of the dovetail piles, nor upon the tops of them; for the weight of the brick-work built

built upon them, will make it bed close to them, provided they have been sawed off level, and as true and even as they ought to be. The bricks for this use should be of the best sort, and very well burnt. The bottom-work being constructed in this manner, the materials will continue perfectly sound, and no water can ever penetrate through or under it.

The brick-walls of the thoroughs *abcd*, should be carried up together with the cross or breast-wall *w*, *w*; for the middle walls *b*, *c*, 14 inches thickness may be sufficient; but the two outside walls *a*, *d*, should be at least 2 bricks and a half, or 22 inches thick, as they will serve as abutments to the breast-wall, and help to support it against the weight or pressure of the head-water.

The breast-wall, as high as the water rises, and walls of the thoroughs, should be laid in tarris-mortar, but it is not necessary that they should be built wholly with that mortar. It will be sufficient if the

the bricks are laid in tarris, 3 or 4 inches into the walls next to the water, and the reſt with other good mortar. The tarris is peculiarly adapted to brick or ſtone-work built in water. The thoroughs of mills built with this mortar are almoſt immediately fit for uſe. The violent current of the water is not able to waſh it out of the joints of the work, though let in upon it but a few hours after it is built; but on the contrary it ſwells or grows out of the joints, and hardens to ſuch a degree, that no run of water affects it.

The bottom of the thoroughs ſhould be paved with bricks ſet on edge, or two courſes of them laid flat, and laid wholly in tarris-mortar, from the breaſt-wall to to the length of ſome yards below the wheels. Some perſons may be apt to think that this method of conſtructing the bottom is in a great meaſure a needleſs expence; but let ſuch be aſſured, that too much precaution can ſcarce be uſed, to guard againſt the force and penetration of water, raiſed to any conſiderable height above its common level; and it is certain from experience, that a great deal more is ſaved in the end, by beſtowing a little more expence to conſtruct ſuch works at firſt effectually; than to perform them ſuperficially, and be obliged to rebuild them in a few years, from a decay of the materials; or, which not unfrequently happens, by the water forcing a paſſage underneath, and blowing up the work.

The conſtruction with ſtone differs in nothing material from brick; and either of them may be uſed with ſucceſs, that is cheapeſt, or can be moſt conveniently obtained.

The dovetail piling and breaſt-wall are to be continued in length, through the banks of the river on each ſide, if the length of the mill extends ſo far: but if it does not, the brick-wall may be finiſhed at each end of the mill with ſtrong quoins of brick-work, and the dovetail

piling

piling continued through the banks, or three or four yards into them, to prevent the water penetrating round the ends of the piling; obferving not to cut the heads of the piles that run into the banks fo low as thofe joining to the wall; but to leave them as high as the top of the banks, or to fuch a depth only below the furface of the ground, that they may remain always wet, and by that means be covered from the air, and their tops fecured from decaying.

It is ufual to continue the walls or wharfing of the head-word with wings, carried up a little higher, and nearly at right angles with the breaft-work. Thefe wings are a fort of wharfing next to the water, and intended to prevent the water getting round behind the breaft-work: but in conftructing thefe wings, great care fhould be taken to make them very clofe and impervous to the head-water, as deep as the breaft-work; and that they fhould join perfectly clofe to the breaft-work, fo that

that no water can get in between them. The wings ſecure the banks from mouldring down, as far as they go, but are not neceſſary to prevent the water getting round; for the dovetailed piles, if continued far enough into the banks, are an effectual ſecurity againſt the penetration of the water there, without wings.

Though this method may appear expenſive, it is not ſo much more than the common conſtructions, as it may ſeem to be at firſt ſight. For it is cuſtomary to lay an apron or ſheeting of boards, ſometimes one above the breaſt-wall, and always one below it in each thorough, to prevent the earth there being carried away, by the force of the water iſſuing through the penſtocks, which otherwiſe it would be to a great depth, and occaſion the blowing up of the bottom in a ſhort time. And under each of theſe aprons there muſt be frames of timber, to which the aprons are faſtened. If to this

this is added the piling to each apron, it will appear that the difference of the expence is not very great, for neither aprons, timber-frames, nor the common piling, is neceſſary in the above method of conſtructing the bottom-work.

Where there is a plenty of ſtone the bottom-work may be done at a ſmall expence, and very ſubſtantially, and the the bottom of the thoroughs being done with large blocks, they will lie very firmly, and not liable to be diſplaced by the current of water, which having the greateſt velocity next the penſtock, the bottom pavement ſhould be laid deepeſt there, and may be of a leſs depth gradually, from thence to the tail or further end of the thorough. In this way of conſtructing it, and laying the work in tarris-mortar, the bottom will be perfectly ſecure, and in no danger of blowing at bottom, nor of diſplacing any of the pavement at top.

In many places where ſtone cannot be got at a moderate expence, chalk may: and chalk is eaſily cut into ſquare blocks, before it is thoroughly dry, which it ſhould be before it is made uſe of in ſuch work: and when it is ſo, and laid in tarris-mortar, will remain firm, and not ſubject to decay under water, nor to wear by the water running upon it; but will contract a kind of moſs or thin cruſt upon it, that will defend it from the water.

There are different ſorts of chalk, or different degrees of hardneſs: ſoft ſoapy chalk is not proper for this purpoſe; but in moſt places where chalk is found, it is of a conſiderable depth, and lies in ſtrata or beds like free-ſtone, and may be raiſed in large blocks, which harden when expoſed for ſome time to the air and ſun in ſummer; but if dug and expoſed to the weather and froſt in winter, being then wet or moiſt, will be apt to crack and break in pieces: for which

reaſon

reaſon chalk that is intended for ſuch bottom-work, ſhould be raiſed in the beginning of ſummer in blocks, and laid to dry and harden in the ſun and air, and then it will be in fit order for this purpoſe.

In ſuch places where neither good bricks, ſtone, nor chalk are to be had at a moderate price, there is another method of conſtructing the bottom-work of mills, and other machines worked by water, viz. by a kind of cheſt-work, reſembling the ancient method of conſtructing the walls of cities, caſtles, and other ſuch buildings; viz. making a cheſt with a double row of planks, placed parallel, and as wide apart, as the intended thickneſs of the wall. Stones and flints of different ſizes were thrown into this cheſt till full, and then a ſtrong liquid mortar was poured into it, which filled the cavities between the ſtones, and cemented them together into one body, ſtrong enough to ſupport the reſt of the wall, raiſed by degrees in the ſame manner; which in time were conſolidated, as we now ſee the remains of many of them, as if a whole wall conſiſted of one ſolid ſtone.

Similar to this, the bottom work may be conſtructed with flints, or common ſtones, and tarris-mortar: as ſuppoſe that a double row of dovetailed piles are driven, parallel to one another, and as far or a little farther aſunder than the propoſed thickneſs of the breaſt-wall; the ſpace between the piles is to be partly filled with the ſtones, and then tarris-mortar as high as the ſtones, to fill up the cavities: put in more ſtones, and then tarris-mortar, till the work is raiſed to the intended height. There is an advantage in this kind of work, which could not be had in the ancient way of building walls. For they required time to dry and harden the work; but the tarris-mortar ſetts and hardens quickly, if any water is let into it: for which reaſon

reaſon a ſolid ſubſtantial wall for a foundation, may in this manner be made in a ſhort time. The heads of the piles being cut off level with the bed of the river, and planked at top, a wall may be raiſed upon this, in the ſame manner as upon any other foundation.

The locks of the Bath navigation are built with ſtone, and the engineer who conſtructed one of them, told me ſome years ago, that they had a ſtrong lime whereof the mortar was made, which was got from a kind of hard ſtone in that neighbourhood. This lock was of more difficult conſtruction than the others, and the river being confined there by riſing ground on both ſides, was ſubject to ſudden floods after haſty rains. This happened once when his men were in full work, and the torrent was ſo high and impetuous, that the men were obliged to leave their work of a ſudden. As the floods there riſe quick, and are very rapid, they are of ſhort continuance, and next day, or day following, the men returned to their work, when they found that part of the materials and moſt of their tools were forced into the river by the ſtrong current, and carried to ſome diſtance below: but what was moſt remarkable, the mortar they had made was hardened to the conſiſtence of ſtone; and their trowels that happened to be left in the mortar, could not be got out without breaking the mortar with hammers.

There is little reaſon to doubt, that ſtone of the like kind may be found in other places, if diligently ſought after; and a lime may be got from it, that with good ſharp ſand, waſhed, would anſwer the purpoſe of tarris-mortar; and not only at a cheaper rate, but in ſome reſpects preferable to the tarris; which though it is excellent for water-works, is not ſo proper as other good mortar for common building, but the above Bath-mortar, is fit for all buildings in or out of water.

The

The water-wheels of ground-ſhot mills erected upon rivers, are not uſually worked by the water of the main river; but, as in the Thames where locks are made, part of the water is diverted out of the river a little above the lock into another channel, and upon this the mill is erected.

Where there is a conveniency of diverting part of a river in this manner to a good diſtance below, as ſuppoſe a mile; in that diſtance the deſcent may be ſuch, that a very good head of water may be obtained to work a mill erected there. As ſuppoſe the difference of the level from the river to the mill to be only 8 feet, a head of water of that height would drive one or more breaſtſhot-wheels, and do a great deal of work; and ſuch a mill may be built to ſtand clear of back-water; which is a great obſtruction to breaſtſhot-wheels.

In making a channel to conduct the water, it is done at the leaſt expence

upon

upon the ſide of a ſloping ground, as in that caſe there is only one bank to be made on the lower ſide, the natural ground on the upper ſide making an excellent bank, without any expence at firſt or afterwards, as it will want no repairing; and the earth dug out of the canal will ſerve to make the bank on the lower ſide. If the ſoil for that purpoſe happens to be a gravel, the water in the canal will penetrate through ſuch a bank, and cauſe a conſiderable leakage: for which reaſon it will be neceſſary to make a ſmall ditch near, and parallel to, the bottom of the bank, to receive and carry off the leakage. Water contains in it a ſlimey ſubſtance, which will inſinuate into the cavities of the gravel, and cement it ſo cloſely, that after ſome time, the banks of gravel become the ſtrongeſt and cloſeſt of any, as experience ſhews.

A canal of about 8 feet wide and 2 and a half feet deep, will ſupply the mill with 20 cubic feet of water per ſecond, running

running at the rate of 1 foot per ſecond; and a canal of theſe dimenſions may be dug, and the lower bank raiſed with the earth dug out, for about 10 pence for every yard in length, and in many places for much leſs; eſpecially if the earth of the canal is firſt looſened with a plough. But at 10 pence per yard the expence of making ſuch a canal of a mile in length, will amount to about 200 l. This, by ſome perſons may be ſuppoſed a low eſtimate; and allowances are to be made, if the ground to be dug was rocky, that required to be blaſted; or a very hard gravel that muſt be looſened with pick-axes. But for common earth, that may be eaſily dug with a ſpade, this eſtimate is too high.

The late Mr. Wood of Bath, agreed to cut one of the canals of the Bath navigation, through a ſtrong clayey ſoil, at the rate of 2½d. per cubic yard; but when he came to treat with labourers there to perform it, they demanded as

much

much or more, than he was to receive for doing it: upon which he brought a number of labourers from London, who performed the work, and threw the earth upon the banks on each ſide, for three half-pence per cubic yard, and at that rate earned good wages. The cutting of the above canal is reckoned at near that price, though not worth ſo much; as this is not ſo deep nor more than a third part of the breadth of the Bath canal; and conſequently not near ſo much labour to throw out the earth.

The depth of 2 feet and a half, may be ſufficient to ſupply the mill, but if the river will not at that depth furniſh a conſtant water, it will be proper to cut the canal deeper, that the mill may have water enough at all times; and if it draws then too much from the river, the canal may be made narrower, but of the neceſſary depth, and not deeper than is neceſſary, as that would be an abatement of the head-water at the mill, which ſhould be raiſed as high as can conveniently be done. A mill erected upon this plan, may be ſo conſtructed, as to be entirely free from back-water, and be no way ſubject to floods, or want of water.

F I N I S.