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THE PRINCIPLES OF AGRICULTURE AND VEGETATION.

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THE

DESIGN.

THE *Edinburgh* ſociety, eſtabliſhed in the year 1755, for the improvement of arts and manufactures, named, amongſt other articles, the following:

For the beſt diſſertation on vegetation and the principles of agriculture, a gold medal.

In order to promote ſo uſeful an inſtitution, the following papers were compoſed, and delivered in to the ſociety, according to the rules laid down. The judges named for that article, determined, on a competition, in their favour. Some few additions have been made to them ſince they were given in to the ſociety.

In ſo neceſſary an art, where the terms are inaccurate, confuſed, and differ ſo much in different counties, to fix theſe terms, and aſcertain their meaning; where there is nothing ſyſtematic, to lay down a regular plan; where the different parts are generally looked on as complete, to mark the deficiencies, and ſhow that there is much wanted; where the means of improvement are unknown or neglected, to point out the only road that can lead with certainty to it; where there are few experiments to build on, to relate ſome, and on theſe to lay a foundation for more; where the reaſonings are, in general, ſo very unphiloſophical, to ſettle ſome fund for diſcourſe and argument; where the proper helps have not been called in, to make uſe of theſe, and introduce a new ſcience to the aſſiſtance of this art; in ſhort, where there is but little aſcertained, to fix ſome general principles on which the artiſt may depend: this is the deſign of the following papers. That no more has been done, will be moſt readily excuſed by thoſe who are beſt acquainted with the difficulty of the undertaking.

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THE

THE

PRINCIPLES

OF

Agriculture and Vegetation.

PART I.

SECTION I.

Causes of the slow progress of agriculture; connection of chymistry with it; and division of the subject.

AGRICULTURE, though the most necessary, has been, perhaps, the most neglected of all the arts. Every other art has undergone considerable improvements in this and the last century; but we cannot affirm the same of agriculture. It seems to be little better understood in *Europe* at present,

than

than amongſt the antients; and I believe *Virgil* and *Columella* may ſtill be reckoned the beſt authors on that ſubject. Does this proceed from the earth loſing, like a mother, her fertility, becauſe of her age? as ſome of the antients alledged: or does it ariſe from an impoſſibility of reducing the culture of the ground to a regular art, as the effects of that culture depend more on chance than ſettled principles? Daily experience ſhows, that none of theſe can be the caſe: for the earth, though exhauſted, attains again, under proper management, a great degree of fertility; and the regularity with which affairs are conducted, ſhows, that it is in ſome meaſure already reduced to an art

THE ſlow progreſs of huſbandry may be accounted for from more obvious reaſons. This art is, in general, carried on by thoſe whoſe minds have never been improved by ſcience, taught to make obſervations, or draw concluſions, in order to

attain

attain the truth; or by thoſe who, although Nature has been very bountiful, cannot carry their ſchemes into execution, from the narrowneſs of their fortunes. The former can never know more than what they have learned from their fathers; the latter dare riſk nothing, as their daily bread depends on the certainty of ſucceſs. What can be expected from that claſs?

Let us ſuppoſe the fortune eaſy, and the judgment improved, the difficulty of the art itſelf is ſufficient to retard its progreſs. How delicate the circumſtances that muſt attend each experiment! What a number of different obſervations on heat and cold, dry and wet, difference of ſoils, grains, ſeaſons, *&c.* muſt be exactly made, before one can be certain of the general ſucceſs of an experiment! What a diſagreement from a ſmall difference in one of theſe circumſtances! How ſeldom can theſe experiments be repeated, which take a whole year before they can be brought to a conclusion! how unequal for such a task are the few years of judgment and activity we enjoy! How liable are observations to die with the observer when not made public! and how averse is human pride to do it, unless it could erect a system! Agriculture, seemingly so easy, appears, from the scarcity of good authors, to be the most difficult of all arts.

BUT these are not the only obstacles that husbandry has met with. It has yet had a greater to struggle with. It does not, like most arts, lead to an account of itself; or depend on principles which its practice can teach. Something beyond this art is necessary to the knowledge of the art itself. The principles of all external arts must be deduced from mechanics or chymistry, or both together. Agriculture is in the last class; and though it depends very much on the powers of machinery, yet I'll venture to affirm, that it has a greater dependence on chymistry. Without a knowledge in the

the latter ſcience, its principles can never be ſettled. As this ſcience is but of late invention, and has not yet been cultivated with that regard to utility, and the improvement of trades and manufactures, as it ought and might, agriculture is hardly ſenſible of its dependence on it. The deſign of the following ſheets is to make this appear; and to try how far chymiſtry will go in ſettling the principles of agriculture.

I don't intend in the following remarks to ſettle facts, or teach the practical part of farming. That I leave to farmers. My deſign is only to ſketch out the great outlines of this art, and ſhow, that it is capable of being reduced, like others, to a regular ſyſtem. If in this way we can fix ſome ſettled principles from the facts which are already aſcertained, thoſe who apply to practice will find their benefit in it. The juſt theory of an art leads directly to its improvement, as it leads to thoſe experiments which yet remain to be tried. Without this guide we may ſtumble on truths by accident; but when led by it, we have the ſecret ſatisfaction of thinking, that we are indebted to ourſelves for the happy iſſue of the experiment.

LET us try to find ſome fixed point from which we may have a full view of this extenſive art, and from which we may proceed, in a methodical manner, to the diviſion of our ſubject. All organized bodies receive their increaſe from the reception and application of certain particles, which are deſigned by the Author of nature for their nouriſhment. Without theſe nutritive particles there could be no increaſe. As plants belong to the claſs of organized bodies, they thrive in proportion to the quantity of nouriſhment they receive at their roots. Hence ariſes a ſimple, but very comprehenſive, view of huſbandry. The whole of the art ſeems to centre in this point, *viz.* nouriſhing of plants.

BUT

But how can the farmer underſtand the art of nouriſhing plants, unleſs he knows the nature and qualities of each kind of ſoil, whether it be proper or improper for that office; unleſs he can provide ſuitable food for the nouriſhment of plants, and diſcovers what that food is; unleſs he aſſiſts the plants in reaching and acquiring that food, by rendering the ſoil looſe and open; unleſs he knows, and endeavours to remove, ſo far as lies in his power, all impediments to this nouriſhment? Theſe are the great outlines of agriculture. In following theſe, then, we ſhall divide our ſubject into five parts. 1. The nature and qualities of different ſoils. 2. The nature and qualities of the different compoſts. 3. Their manner of acting. 4. The different methods of opening the ſoil. 5. The impediments to vegetation, and their cure.

The operations of bodies are to be accounted for only from their known qualities aſcertained by experiment. Reaſoning on any other plan, can never certainly lead to truth. I ſhall not, therefore, proceed a ſingle ſtep without fact and experiments; and when I am not ſupplied with them from others, ſhall endeavour to make them myſelf. It is laborious, but it is neceſſary.

SECT. II.

Of different ſoils.

AS the earth is the matrix to which all ſeeds are committed, and from which all vegetables take the whole, or at leaſt the greateſt part of their nouriſhment, it is proper to begin with an examination of it. As it nouriſhes plants without the aſſiſtance of art, it muſt contain the food of plants. If we can diſcover what is the natural food of vegetables, we ſhall the eaſier diſcover wherein conſiſts their artificial food, or that given by art, and how it operates.

EARTHS are found to differ very much from one another in their qualities; farmers have therefore divided them into several different kinds, and perhaps have run into too minute divisions. It is difficult indeed to settle the exact limits betwixt the different soils; but such difficulty we find in all the divisions of natural bodies. The Author of nature has connected different bodies by intermediate ones; he has chosen to act by different gradations, and not by starts, that nature may appear one connected whole. The great division, or the specific difference of earths, may be reduced to these six, *viz.* rich black soil, commonly called *loam* or *hasley* soil; clay; sandy; mossy; chalky; and till.

WHEN farmers treat of these soils, they generally distinguish them from one another by the colour, or some other superficial quality, which immediately strikes the senses. But colour can never lead to the composition or principles of bodies, on which

which alone their effects depend. Such ſuperficial qualities as that, depend themſelves on the conſtituent parts of bodies. We ſhall then endeavour, by experiment, to detect the conſtituent parts of theſe different ſoils, and ſhow wherein they differ from one another.

SECT. III.

Of the rich black ſoil.

I Begin with this ſoil, as it is found to contain the greateſt quantity of vegetable food, and as all other ſoils are richer or poorer in proportion as they contain more or leſs of this.

THIS ſoil, when freſh dug up, and ſufficiently moiſt, has a very agreeable ſmell, which is not felt when it is too dry or too wet. We are very ſenſible of an agreeable ſmell in the fields after a gentle ſhower of rain, eſpecially if a drought has preceded.

preceded. This we attribute to the effluvia of the plants: but it belongs to the earth, as it is to be felt every where, and ſtronger the nearer the noſe approaches the ground. This is probably owing to the volatile ſalts and oils, which riſe together, in greater plenty, as the natural fermentation of the earth is increaſed by a due proportion of moiſture. See a Treatise of Agriculture Edin. 1762 p. 407.

To crumble when dug up, is a quality peculiar to this ſoil. In this it differs very much from the clay and ſandy ſoil. The former does not ſeparate; the latter falls into a powder like ſand; but this ſeparates into ſmall bits. It ſeems to enjoy that degree of coheſion which is fitteſt for ſupporting vegetables, and at the ſame time allowing their fibres to ſpread in ſearch of their food. The particles of this ſoil ſeem to be in a continual tendency to recede from one another; for it is obſerved, that when dug up, and expoſed to the air, the hole from which it was taken, will not again

again contain the quantity taken out. This muſt be owing to a fermentation of the putrefactive kind, carried on, in a ſmall degree, in theſe rich ſoils, whenever the air is admitted to them: for without air there can be no inteſtine motion. This continual tendency to putrefaction, in ſome of the particles of this ſoil, will appear more plain from its colour, and quantity of oil, the only ſubject of corruption. Hence it follows, that there muſt be a degree of heat in this ſoil, in proportion to the progreſs of the putrefactive fermentation, and independent of the ſun, or natural heat of the internal parts of the earth.

THIS ſoil admits the water eaſily, and ſwells like a ſpunge after it has taken the moiſture in. This quality is peculiar to good ſoil. It contracts again when dried. Hence naturaliſts conclude, that this ſoil conſiſts of ſpungy and ſwelling particles. I rather chuſe to attribute this ſwelling to the

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fermentation, or inteſtine motion, which continually goes on in this ſoil, being increaſed by the addition of the water; for all bodies muſt have a certain degree of watry particles, in order to make the fermentation go on properly.

It is obſerved of all ſoils, the moſſy and boggy ground excepted, that the blackeſt are the richeſt. This colour gives us a ſtrong preſumption, that theſe ſoils contain much fat and oleaginous matter; for all foſſil and vegetable oils, when they have a great admixture of earth, are of this colour. It is owing likewiſe to theſe oils, that all vegetable or animal ſubſtances gain a black colour when in the road to putrefaction. The unctuoſity too of this ſoil, a quality of it which is remarked by farmers, is a proof of its oleaginous nature. This black colour will make it reflect fewer of the ſun's rays, and ſo make it ſuſceptible of a greater heat, than ſoils which are of a lighter colour.

BUT

But we have a certain method of knowing, whether a body contains any oleaginous particles or not, by the means of nitre melted in the fire. Nitre, though not inflammable of itſelf, becomes, in this ſituation, inflammable, or, as the chymiſts chuſe to call it, deflagrates with bodies which contain any oily particles.

Exp. 1. Some rich mould taken up three or four inches deep from the border of a garden where no dung had ever been laid, deflagrated very much with nitre in fuſion. Hence it appears, that this ſoil contains much oil.

To diſcover if this earth contained any abſorbent or alkaline particles, I tried the following experiment.

Exp. 2. Some ſtrong vinegar, diluted with twice its quantity of water, being poured on this fat earth, raiſed a gentle fermentation, from whence many air-bubbles arofe; the acid tafte was at leaft deftroyed, and the vinegar reduced to a neutral body. From this experiment we learn, that rich mould contains a great many particles which attract acids, and with them make a neutral falt. I have learned from many different trials, that all foils fit for the nourifhment of plants, contain more or lefs of thefe antacid particles.

To difcover what we fhould get from this earth by diftillation.

Exp. 3. I diftilled half a pound of it with a gentle heat; I got in two hours an ounce of a yellow empyreumatic liquor, which was of an alkaline nature. The ftrongeft fire continued for nine hours longer, gave half an ounce more of a yellowifh empyreumatic liquor, which had feveral oleaginous filaments fwimming in it. It fmelt like fpirit of hartfhorn, turned fyrup of violets green, and effervefced ftrongly with vinegar.

FROM

From this experiment it appears, that the ſalts of this ſoil are of the volatile alkaline kind; and that theſe ſalts naturally exiſt in it, as they riſe with a ſmall degree of heat. From this likewiſe we have another proof of oil being contained in this ſoil, as it tinged the firſt water with a yellowiſh colour, gave it a burnt ſmell, and was plainly to be diſcovered in the ſecond floating about in a filamentous way.

SECT. IV.

Of the clay ſoil.

THE clay ſoil is very different from the former; and as it is a compoſition of clay with a mixture of the former ſoil, we ſhall inquire into the properties of clay.

The diſtinguiſhing and characteriſtical property of this body is, that having already got a certain quantity of moiſture, it reſiſts,

resists, in some measure, the entrance of more water into its pores, is very slowly penetrated by that fluid, and therefore is not in any great degree softened, loosened, or otherwise affected by it. Clay, when pressed by external force, or firmly compacted by its natural subsidence, as we find it at the bottom of many of our soils, and of most of our mosses, will even sustain water, and become impenetrable to it. Hence soils, in proportion to the quantity of clay they contain, will hinder the water from passing through them; will keep the vegetables continually soaked in moisture; will not be so much heated by the rays of the sun as if they were dry; and, therefore, are justly deemed of a cold nature.

WHEN exposed to the degree of heat of a summer sun, clay dries, and turns very hard, so that it requires a considerable force to separate its parts. This quality of clay is the more observable, if it has been full of moisture, and dried suddenly. Hence clay grounds are ſo apt to cake with heat, eſpecially if they have been ploughed wet, and will, in that ſtate, hinder the roots of vegetables from paſſing through them.

THESE qualities of clay ſeem to depend on the ſame cauſe, *viz.* the ſtrong adheſive power of its particles. Its great ductility ſhows, that its particles adhere very firmly. But whence this adheſion? Is it from a certain figure of its particles, by which they are intangled, and can it be ſo eaſily ſeparated? or is it from oleaginous particles mixed with the earthy, as we know that oil is adheſive, and rejects water? I incline to the latter opinion, as I have found that clay contains an oil, not ſo looſe indeed as in the former ſoil, but intimately connected with its earth, and ſcarcely ſeparable from it.

Exp. 4. I mixed ſome clay with vinegar; but there was no fermentation, and the acid taſte was not blunted. It ſeems then to have

have neither alkaline nor abſorbent particles in its compoſition. In this it differs very much from the former ſoil.

CHYMISTS generally aſſert, that clay contains an acid of the vitriolic nature, and an oil. From this acid they account for its diſtilling the acids of nitre and ſea-ſalt, and for its vitreſcible nature, as ſalts are the great aſſiſtants of vitrification.

LEMERY le fils, in the *Mem. acad. de Scienc. pour l' année* 1708, has theſe words. *Comme il y a dans l' argille de parties huilleuſes, acides, et terreuſes.* And again, *Car en la pouſſent par une feu plus conſiderable, il s'en échappe des acides et de parties huilleuſes.* Let us ſee how far this is true.

THAT I might diſcover its contents by diſtillation,

Exp. 5. I put into the retort half a pound of dry clay, taken up ſeven feet below the ſurface from a clay-pit then employed in a brick manufactory; and as much ſand was mixed with the clay, it ſeemed to be of a pure nature. After it had been diſtilled for two hours with a gentle fire, I got half an oz. of pure water. After it had ſuffered the ſtrongeſt heat that I could give it in a portable furnace for nine hours, I found in the receiver two drams of a pellucid liquor, which ſmelt like the ſpirit of hartſhorn, effervefced ſtrongly with vinegar, and turned ſyrup of violets green. The remainder was very red.

Thus, inſtead of getting an acid, as the chymiſts aſſert, I have got an alkaline volatile ſpirit. No oil appears from this experiment; and, therefore, we may conclude, that if there is any oil in it, that oil is intimately united and combined with its earthy parts, analogous to what happens in metals.

THAT there is ſuch an oil, ſeveral reaſons induce me to think; its nouriſhing vegetables, which require oil, when opened by mere ſand; its unctuoſity; its igniting, like metals, when put in the fire.

Exp. 6. I tried ſuch clay as I uſed in the former experiment with melted nitre. When ſmall pieces were put in, no fire was produced betwixt it and the nitre: but I evidently perceived ſparks of fire when it was put in powdered. Hence I conclude, that clay contains an oil intimately and cloſely combined with its terreſtrial parts.

THE oleaginous nature of clay is clearly demonſtrated by an experiment of Mr. Eltors, in the 5th Vol. of the Berlin Memoirs. He boiled ſome clay in an alkaline lye; this lye when decanted was ſaturated with ol. vitriol. After the liquor had ſtood ſome time, he found at the bottom a viſcid matter which deflagrated with melted nitre, and reduced the calx of lead to its metallic form By this experiment the oil was got in a feparated ftate from the earthy parts, which after this feparation had loft their tenacity. This gentleman's experiments fhow us how ftrongly the oil and earth adhere; for the oil was fcarcely feparable by fpirit of wine.

Exp. 7. When a piece of the clay was kept in the kitchen-fire for fome time, it turned red like a live coal, and when taken out, had a high red colour, which feemed owing to the particles of iron that it contained. Very few particles indeed were attracted by the magnet. But it muft be remembered, that this quality depends upon the inflammable part of that metal, which is always given it by art, and that I had not added oil in the calcination. Very few ores have this quality naturally. All thefe experiments were made on the fame clay.

SECT. V.

Of the ſandy ſoil.

THIS ſoil gets its name from the quantity of ſand which it contains. The qualities of this ſoil depend on the qualities of ſand. This body differs much from the two former; from the latter, as it eaſily admits the entrance of water; from the former, as it does not detain the water like it, which ſeems to attract moiſture with conſiderable force, and to reſiſt its eſcape again; while ſand allows it to paſs eaſily through its body, and does not ſwell, but, on the contrary, turns leſs in bulk, when wet. Sand cannot detain the water ſo long as the rich ſoils, becauſe it does not contain thoſe ſaponaceous and mucilaginous juices which theſe do, and with which the water is combined and detained. Hence ſandy ſoils often want a ſufficient quantity of moiſture for the nouriſhment of plants. Hence they

they are very hot, becauſe ſand is ſuſceptible of a greater heat from the influence of the ſun, and will retain it longer than water does.

SAND cannot ſwell by the addition of water; becauſe that quality in rich ſoils is owing to an inteſtine fermentation, which goes on in them. But in ſand there are no particles, and in ſandy ſoils too few, which are capable of fermentation. Hence a defect of nutritious particles in ſandy ſoils. Inſtead of ſwelling, it diminiſhes in bulk when wet; becauſe the water ruſhing in, diſpoſes the particles more regularly, ſo that the interſtices are better filled up than before, and its bulk leſſened.

THE faults, then, of the ſandy ſoil are, that it lets water paſs through it too eaſily, and that it contains too few nutritious particles. Whatever compoſt is uſed to this ſoil, muſt correct one or both of theſe faults. Clay will help it to retain the water;

ter; but then it is not richly ſtored with vegetable food. Woollen rags anſwer both purpoſes very well, as they contain a great quantity of mucilaginous juice, which ſerves equally well in nouriſhing plants, and in detaining moiſture.

The compoſt that appears to me to be one of the fitteſt is moſs: for it is as impervious to water as clay, nay perhaps more ſo; and as it is a vegetable, contains more oil than any other that I know. This reaſoning is confirmed by fact. A gentleman laid ſome of this manure on a ſmall part of a field, conſiſting of a very light ſandy ſoil. The oats which grew that year, and the clover which grew the following, were much better on that part than on the reſt of the field. See a Treatise of Agriculture Edinb. 1762. p. 422. n.

The following experiment was tried on equal portions of about three feet ſquare, in a very light ſandy ſoil, during the laſt ſummer,

ſummer, which being very dry makes the experiment more concluſive.

Exp. 8. N° 1. was covered and incorporated with two inches deep of clay. N° 2. with three inches. N° 3. with four inches. N° 4. had two inches of clay with the common quantity of lime laid on ground. N° 5. had three inches of clay with the ſame quantity of lime. N° 6. had four inches of clay with the ſame quantity of lime. N° 7. had two inches of clay with the uſual quantity of dung. N° 8. had three inches of clay with the ſame quantity of dung. N° 9. had four inches of clay with the ſame quantity of dung. N° 10. had ſix inches of clay. N°. 11. had the ſame with lime. N° 12. had the ſame with dung. N° 13. was the light poor ſandy ſoil without any addition. N° 14. had the uſual quantity of lime added to the ſoil. N° 15. had the uſual quantity of dung added to the ſoil.

July 2. N° 1, 2, 3, 4, 5, 6. are all bad. N° 7. very good. N° 8, 9. exceeding good. N° 10, 11. very bad. N° 12. exceeding good. N° 13. is the worst of all, and scarcely bears any thing. N° 14. bad. N° 15. pretty good.

August 13. N° 1, 2, 3, 4, 5, 6. bad. N° 7, 8, 9. exceeding good and heavy grain. N° 10, 11. are all withered. N° 12. exceeding good. N° 13, 14. carries nothing. N° 15. pretty good.

FROM this experiment the following useful conclusions arise.

Corol. 1. A poor sandy soil, when of itself it was able to produce no grain in a dry season, was fructified to a considerable degree by dung alone; but clay alone, and lime alone, did it but very little service.

Cor. 2. Light sandy soil is not much benefited by a mixture of clay and lime; but

but clay and dung enrich it to a prodigious degree, and make it capable of bearing a dry ſeaſon, which of itſelf it can ſo little ſtand. While all vegetation was ſtopt in the ſoil alone, an addition of clay and dung produced one of the beſt crops that I ever ſaw.

Cor. 3. Though theſe concluſions agree in general with regard to all ſorts of grain, yet as different kinds were ſown, I obſerved that oats agreed better with clay, and clay and lime, than either barley or peaſe; but that the two laſt agreed better with the clay and dung than the oats.

SAND, however hard it is, ſeems to be moſtly compoſed of a mucilaginous, oily ſubſtance; as appears by the following trial.

Exp. 9. *February* 9. I put ten gr. of pure ſea-ſand, pounded in a mortar, into a phial with one drachm of oil of vitriol; the ſame quantity

quantity of ſand with the ſame quantity of ſpirit of nitre, in another glaſs; the ſame with ſpirit of ſea-ſalt, in a third. *March* 28. the acids appeared turbid. I mixed with each ſome water, that I might get the ſand eaſier away by itſelf, and that the particles mixed with the acids might be more eaſily ſeparated. The ſand in the firſt glaſs weighed 7 gr.; and that in the ſecond and third, 6½ gr. That I might precipitate from the liquors whatever was diſſolved by the acids, I mixed with each as much pearl aſhes as was neceſſary to ſaturate the acids. After the effervescence was over, there was a browniſh oozy powder at the bottom of the *ol. vitriol.* and an oily ſubſtance at the bottom of the other two, which was quite diſtinct from the water. What was precipitated from the ſpirit of nitre, was yellow; from the ſpirit of ſalt, was white. The former, when ſeparated from the water, deflagrated with melted nitre, which ſhowed it to be of an oily nature; but the latter did

not.

not. I muſt obſerve here, that the fine powder of flint has a ſenſible deflagration with melted nitre.

As lime is a powerful diſſolvent, eſpecially of oily bodies, I imagined that lime might have ſome ſuch effect on ſand, diſſolve it into a mucilage in the earth, and in this way ſand might be converted into a fit nouriſhment for vegetables. This perhaps might be, I thought, the reaſon why lime and ſand took ſo firm a bond together, when lime alone does not adhere. This appeared to me yet ſtronger, when I conſidered, that any mucilaginous or oily ſubſtance, ſuch as whites of eggs, train-oil, &c. when mixed with quick-lime, make it take bond. I therefore tried the following experiment.

Exp. 10. I took a certain number of ſmall pieces of flint, which is allowed to be of the ſame nature with ſand, weighing 1 dr. 52½ gr. and added a quantity of lime

lime and water to them. They lay amongst the lime from the 9th of *February* to the 23d of *March*. When taken out, and dried, they weighed the same as when put in.

Exp. 11. That I might see what effect the mucilage extracted from sand by the acids, would have on quick lime, I added a very small quantity of the mucilage from both acids to quick-lime, and baked them together into a paste. Some of the same, lime was made into a paste with water alone. After they had lain for four weeks, and were entirely dry, neither of them had taken bond.

THESE experiments would seem to be in opposition to the former theory. The question, however, is of such use, especially with regard to building, that it deserves to be further considered.

SECT.

SECT. VI.

Of the chalky ſoil.

I SHALL ſay little about this ſoil, becauſe, as it is to be found only in few counties in *England*, I have not yet met with it; and I ſhall relate nothing on the faith of thoſe who reaſon without the aſſiſtance of experiment.

CHALK is an abſorber of acids, and has no oleaginous particles in its compoſition, but is a powerful attracter of them. Hence the proper manure for this ſoil muſt be thoſe bodies which contain moſt oil, as hair, rags, *&c.* It ſeems to have but a very weak attraction to water; and, therefore, will be generally too dry. This ſoil is obſerved by farmers to cake after heavy rains.

SECT. VII.

Of till.

FARMERS call thofe foils *till*, which have a reddifh, gray, or yellowifh colour, are poor, will bear nothing, nor can be fertilized fo eafily or fpeedily as the former foils. Sometimes they render all attempts fruitlefs. This foil muft, therefore, not only contain no vegetable food, but it muft often contain a vegetable poifon; elfe it would always become fruitful by the application of compofts. What this poifon is, muft be the fubject of our prefent inquiry; for unlefs we know it, we cannot know whether there is a remedy for it or not.

THE following experiments were performed on fome of this unfruitful earth fhown me by an experienced farmer.

Exp. 12. It effervefced vifibly with vinegar and oil of vitriol diluted with water,

 but

but had a peculiar irony tafte, and turned black with galls,

Exp. 13. Some of this earth calcined in a ftrong fire for two hours, was almoft all attracted by the magnet.

Exp. 14. It did not deflagrate with melted nitre.

Exp. 15. Four ounces of brown till well dried, being diftilled, in fix hours gave two drams of a phlegm, which fhewed no acid or alkaline nature.

FROM thefe experiments it appears, that this fpecies of till contained neither falts nor oils, but was a compofition of earth and iron. The poifonous quality of this foil muft then have depended on the latter body, which we may obferve by the firft experiment is diffolvable in all acids, and in that ftate may enter the veffels of plants. We fhall afterwards fee that it will meet with acids. This reaſoning is put beyond all doubt by the following experiment.

Exp. 16. I took one pound of good rich mould, and mixed with it one drachm of ſalt of ſteel; put it into a pot, and ſowed ſome barley in it in the beginning of *May*. Some of them ſhot up about an inch, looked very ill-coloured and ſickly, and then died; while other grains in another pot, filled with the ſame earth, throve very well.

THUS a very ſmall quantity of iron, diſſolved by the vitriolic acid, rendered a great quantity of rich earth unfruitful, and therefore ought to be looked on as the vegetable poiſon of till. If this poiſon can admit of a cure, I imagine it is only to be found in lime or marl, which will attract the acids from the iron, and make it, at leaſt in a great meaſure, indiſſolvable in water.

THOUGH the admixture of iron with the ſoil may be a very general cauſe of unfruitfulneſs, yet it ſeems not to be the only one. A great deficiency in ſome of the principles neceſſary for vegetation, muſt have the ſame effect. Thus farmers often give the name of *till* to indurated clays, and particularly to thoſe which they find below the ſoil. The common farmer is afraid of ſtirring it up with the plough, becauſe it is unfruitful: but the more judicious, willing to deepen his ſoil, takes it up by little and little, and finds that lime, dung, and air, readily fertiliſe it.

S E C T. VIII.

Of the moſſy ſoil.

I Shall not enter into a diſcuſſion of the origin and nature of moſs: it is now allowed by every body to be a vegetable ſubſtance. The following experiment is a proof of it.

Exp. 17. Half a pound of powdered peat gave me by diſtillation, during the two firſt hours,

hours, 2 oz. of an acid empyreumatic liquor, which was of a yellow colour, and ſhowed its acid nature, by effervescing with *ol. tart. p. d.* The ſtrongeſt fire continued for nine hours longer, gave me 2 dr. of a reddiſh empyreumatic liquor more acid than the former, and 1 ſcr. of a thick dark-coloured oil. There was beſides about the neck of the retort, a great quantity of red oil, which was too heavy to come over. The *reſiduum* was black.

Exp. 18. Some peat burnt in the open fire, gave me about the two and thirtieth part of alkaline ſalt.

HENCE we ſee, that peat affords the ſame principles as other vegetables do, and therefore muſt be claſſed amongſt them.

THE only method, then, to make this ſoil fruitful, is to make the vegetable undergo a degree of putrefaction, by ploughing the ſoil, and ſo killing the plants. All vegetables turn to rich ſoil when they have undergone a degree of corruption; even oak bark becomes in time rich black mould. The parts will be the ſooner ſeparated, if ſome earth or clay is added to the moſs; for moſs of itſelf is rather an enemy to corruption. All kinds of vegetable ſubſtances and animal bodies are preſerved uncorrupted for whole ages in moſs-holes. Abſorbents are known from experience to be promoters of corruption. The various kinds of marl, when they can be got, particularly the ſhell-marl, would ſeem to be the propereſt manures for this ſoil. Lime, as it appears to be a great diſſolvent of all vegetable bodies, may have good effects on this ſoil.

PART II.

SECTION I.

The natural methods of providing vegetable food.

HAVING ascertained the properties of the different soils, the next thing we have to do is, to examine into the nature and properties of whatever is observed by experience to fructify ground, whether it be applied to the soil in a natural or artificial way. If we can discover some qualities in which all these manures agree, we shall arrive at the knowledge of what we are in search of, *viz.* the food of vegetables, or at least of those principles which go to the composition of that food. Let us first inquire into those ways by which nature fructifies the earth.

If earth is exhaufted of its vegetable food, experience has difcovered, that it recovers it again, if allowed to lie idle. This fhows, that the vegetable food is continually on the increafe, when the earth is not robbed of it by the crops it bears. We difcover immediately whence this food comes, when we attend to thefe two facts; that the more the foil is expofed to the air, the vegetable aliment is the fooner procured, and in greater quantity too; and that when the furface is buried by the action of the plough, and a new foil brought up, that foil, though feemingly as good as the former, produces bad crops, till it has received for fome years the benefit of the atmofphere.

Fallowing is a conftant proof of this. The foil is frequently broke down and turned over by means of the plough, and every part of it is expofed to the influence of the air. That the communication of the earth, by the mechanical action of the plough,

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.

BUT this nutritious influence of the air is yet more obſervable in thoſe earthen dikes or walls made of the ſoil taken from the ſurface, and thrown up to incloſe the ſheep-folds. Theſe dikes are expoſed to the influence of the air, which paſſes through and through them for many months. The ſoil thus expoſed is rendered prodigiouſly fruitful, ſo that it is eaſily diſtinguiſhable by the quantity and deep green colour of the grain, from the internal parts of the fold, which have been well manured by the urine and dung of the ſheep. It is likewiſe remarked by farmers, that the earth of the dike laſts for three or four years

years longer fruitful than the other part of the ſheep-fold.

THIS chief inſtrument, then, that nature makes uſe of to enrich the earth, is the air. Even the richeſt ſoils require its continual influence. On what principles of the air this fructifying quality depends, we cannot inquire, until we have aſcertained the nature of the different manures which ſeem to operate by attracting thoſe principles from the air. The ſtrong and laſting vegetative power which the air communicates to the earth, ſhould teach us to make a greater uſe of its influence than what we do. Why ſhould we not raiſe the whole ſurface into fold-dikes? Other manures do not operate till the ſecond or third year after they are laid on; this operates immediately. A farmer cannot, at a medium, dung an acre under 5*l*; this might be done for 30*s*. Dung fills the ground with weeds; this method cleans it. Manures cannot be found every where; this practice may

may be followed in all places. It would be particularly good for clay ground, as the viciſſitudes of the air pulveriſe greatly.

DEW is reckoned by farmers a great fertiliſer of the earth. It ariſes from the perſpiration of the earth, of vegetables and animals in a ſound ſtate, and their exhalations in a corrupted one. The earth retaining its heat, after the ſun's influence is weakened, elevates theſe attenuated particles: but the air cooling ſooner than the earth, from its rarity, condenſes them at a little diſtance from the ſurface; and thoſe which become ſpecifically heavier than the air, fall on the earth again. Hence dew muſt differ according to the difference of the bodies from which it proceeds. Its contents are therefore various; but experiments have diſcovered, that it is compoſed in general of oils, ſalts, and a great proportion of water. Of what uſe theſe principles are to vegetation, we ſhall afterwards ſee.

RAIN-

RAIN-WATER, eſpecially in the ſpring, has nearly the ſame contents. Margraaf, in the Academ. de Berlin, vol. 7. has analyſed it with great accuracy, and ſhowed that it contains a nitrous and a ſea-ſalt, with a conſiderable quantity of an abſorbent earth; which probably was united to a nitrous acid before evaporation, and conſequently increaſed the quantity of nitrous ſalt very much. The ſalts were of a brown colour, which diſcovered its oil. As the water was gathered in the winter, it contained a ſmaller proportion of this laſt body, than if it had been gathered in the ſummer.

SNOW is juſtly reckoned amongſt thoſe bodies which fructify earth. I have obſerved a light floating oozy ſediment at the bottom of ſnow-water, after I had kept it three or four days. When ſnow melts, its ſurface, even in the tops of hills, is covered with a brown powder. Both rain and ſnow-water putrify ſooner than ſpring water; which ſhows

ſhows that they contain more oily particles than it does.

Exp. 19. A pound and an half of ſnow-water being evaporated, gave 2 dr. of a reddiſh liquor, which had little taſte, and diſcovered nothing ſaline in it. I ſet it in a cellar for fourteen days; and when I took it out, it was covered with a mouldy ſubſtance. This mould, when dried, burnt on a red-hot iron to a powder. Hence it appears, that ſnow contains an oily ſubſtance. Margraaf having evaporated a greater quantity of ſnow-water, diſcovered the ſame ſalts and earth as in rain-water.

THE overflowing or water-flooding of low grounds may be reckoned amongſt the natural methods of improving the ſoil; becauſe flat meadows are often naturally overflowed, either by rains, or by the rain-water falling from the higher grounds. *Egypt* is naturally overflowed once a-year by the *Nile*, and rendered by that means exceedingly

exceedingly fertile. Spring-water is even found to be of ſervice to ground, but not ſo much as river-water, eſpecially ſuch as has run through a fertile country, and is, at that time, full of the ſubtiler particles of the ſoil waſhed off from the rich grounds by rains. As theſe waters are impregnated with the ſubtile earth, and the ſaponaceous juices of thoſe ſoils over which they have run, when they ſtagnate, theſe nutritious particles ſubſide, and inrich the ground. The river *Nile* depoſites a rich oozy mud, which is ſo full of putreſcent particles, that its ſteams ſeem to be the cauſe of the plague raging ſo much in *Egypt*. By this addition of ſoil it receives every year, the level of the ground is conſiderably higher than it was. Hence too the vallies in all countries are much richer than the riſing grounds; as the rains waſh great part of the vegetable matter from the latter, and leave it in the former.

ART often imitates nature in this method of improving land, and lets in the ſtreams of rivers to cover the fields. This is moſt frequently done in the ſpring, when theſe waters are moſt impregnated with nutritive particles. This water, after it has depoſited all its particles, which it does in four or five days, is let off quickly; leſt, by a gradual evaporation, it ſhould cake the ground, and hinder the graſs to come up; which is the great danger attending it, and for which it is thought improper for clay grounds.

IT muſt be obſerved here, that there are ſome waters which are extremely prejudicial to grounds, ſuch as coal and ſteel waters. This is owing to the quantity of iron which both theſe contain. All ſulphur waters are likewiſe hurtful to ground; we ſhall afterwards ſee that ſulphur is a poiſon to plants.

SECT. II.

Of manures, or the artificial methods of providing vegetable food.

EXPERIENCE has ſhown, that certain ſubſtances, committed to the earth under certain regulations, make it more fruitful. Theſe ſubſtances belong either to the foſſil, the vegetable, or the animal kingdom. The foſſil include the different kinds of marl; calcarious ſtones, ſuch as lime-ſtone, chalk, *&c.*; and quick-lime. The vegetable include all vegetables, and their juices, either in an intire or a corrupted ſtate; the aſhes of burnt vegetables; the oils extracted from vegetables and ſoot. The animal include calcarious ſhells, intire or corrupted; horn-ſhavings or tips; woollen rags; and all animal ſubſtances, ſuch as dung, urine, *&c.* I ſhall treat of theſe in their order.

I am not to lay down the method of uſing theſe; I ſhall take no notice of that, but where it tends to ſhow their method of operating. My deſign is to take a view of thoſe qualities belonging to them, by which they are capable of operating on the ſoil, and producing certain effects on the vegetation of plants.

SECT. III.

Of marl.

THIS is a foſſil body which feels unctuous and fat betwixt the fingers; and reſembles clay in a great meaſure, inſomuch that marl, though a very different body, is often confounded with it. It is divided into many different kinds, which may be all included under theſe two, clay, and ſlate or ſtone marl: for what is commonly called *ſhell-marl*, is an animal ſubſtance, and therefore to be claſſed amongſt them. The different colours of marl make no real difference as to their properties.

Exp. 20. It is a diſtinguiſhing and characteriſtical property of this body, that, when it is put into water, it falls down into a powder. The clay marl diſſolves much quicker than the ſtone marl. This quality muſt be owing to the weak adheſion of its particles; ſo that the ſmall force with which water enters its pores, is capable of ſeparating the particles of the marl. By this property it is ſufficiently diſtinguiſhed from all the earths which we have mentioned; and particularly from clay, which does not ſo ſpeedily admit the entrance of water.

As marl is ſo much opened by water, ſo as to loſe its natural coheſion entirely, we ſee how much it will favour the eſcape of water from ſuch grounds as have been manured with it. Clay grounds, after they

have

have been marled, become much drier. It is owing, I imagine, to the water getting off ſo quickly, that marled grounds, as is obſerved, are leſs affected by froſt, than the ſame ſoils which have not got any marl.

Exp. 21. It effervefces with all the different acids, and turns with them into a neutral ſalt. During the effervefcence with the oil of vitriol, a ſulphureous ſteam aroſe, which is a ſtrong preſumption of its containing ſome oily ſubſtance. The clay marl ſeemed to diſſolve faſter than the ſtone marl, and deſtroyed about a third more of the acids. This quality which marl has of attracting and deſtroying acids, is one of its diſtinguiſhing properties, without which no ſubſtance can be called marl. In this quality it is likewiſe diſtinguiſhable from clay.

As farmers are extremely inaccurate in their terms, they often give the name of marl to bodies which do not efferveſce with acids. That ſuch ſubſtances may and do fructify ground, is indubitable; but they ought not therefore to be called marl. Surely bodies which do, and bodies which do not efferveſce with acids, are very different in their nature, and ought to have different names. As the name of marl, then, is generally, ſo let it be only applied to the former claſs. The latter ſhould have ſuch names as will diſtinguiſh them from the former. This ſhews what confuſion there is in the terms of agriculture, and how much they ſtand in need of being defined.

Exp. 22. Another quality belonging to marl, by which it is diſtinguiſhed from clay, is, that it cannot be converted to brick. It is indeed very much altered by a ſtrong heat: it loſes its antacid quality while it remains unpowdered; and is no longer diſſolvable in water, as it was be-

fore:

fore: but ſtill it is very different from a half-vitrified ſubſtance; and I much queſtion, whether or not it can, without any addition, be turned into glaſs. This is a ſtrong proof, that it contains no ſalts, acid, alkaline, or neutral; for theſe are capable of vitrifying lime when added to it.

Exp. 23. I could not get any ſalt from theſe marls, either by ſimple lixiviation, or diſtillation, though I urged them with the ſtrongeſt fire. The fire ſeparated nothing but a little water, which appeared to be gently alkaleſcent; owing perhaps to ſome of the finer marly particles, which were carried up by the water. No oil appeared in the diſtillation. When the powder of marl was thrown on fuſed nitre, it ſparkled a very little. This, and the ſulphureous ſmell ariſing when it was diſſolved by the oil of vitriol, would incline me to think, that it has a ſmall proportion of an oleaginous matter in its compoſition.

But though perhaps it contains none, yet it ſtrongly attracts all oils. This is a quality which the chymiſts know belongs to all abſorbent earths; theſe they make uſe of to ſeparate oils from other bodies. Hence it will attract and fix the oils which it meets with in the ground, which fall with the ſnow and rain; and even thoſe which, floating in the air, touch its ſurface.

To inquire a little further into its nature, and ſeparate its antacid parts from the others, that we might diſcover both; *Exp.* 24. I took half an ounce of ſtone marl in powder, and ſaturated it with ſpirit of nitre, by adding the acid in ſmall quantities for five days; the ſaline liquor was filtred through brown paper. There remained in the paper three drachms of a bluiſh adheſive earth, which, on trial, appeared to be a fine clay. To recover the other part from the ſaline liquor, I added *ol. tart. p. del.* till no more lactiſcency appeared;

peared; a white ſubſtance fell to the bottom, and was ſeparated from the liquor by filtration. This powder being waſhed with water, that all the ſalts might be ſeparated from it, and calcined in a ſtrong kitchen-fire for five hours, gave me a quick lime, which afforded good lime-water.

From the ſame quantity of clay marl, treated the ſame way, I got three drachms and twenty-eight grains of clay, and thirty-two grains of a calcarious earth.

From the ſame quantity of clay marl, ſaturated with vinegar, and treated the ſame way, I got two drachms and fifty-nine grains of clay; and the remainder was a calcarious earth, which, being burnt, afforded good lime-water.

The ſame quantity of a different clay marl, treated the ſame way, afforded two drachms and fifty-four grains of clay, and one drachm ſix grains of a calcarious earth.

THE ſame quantity of ſtone marl, treated the ſame way, afforded juſt the ſame proportion of clay and calcarious earth.

MARL, then, is a body compoſed of lime and clay in different proportions, according to the different kinds of marl, and generally about one fourth of lime and three fourths of clay.

FROM this experiment we may eaſily account why marl falls in water, as lime ſtrongly attracts water; and why it loſes this property when burnt, as clay becomes more tenacious by fire; why it cannot be converted to brick, as the lime hinders that cloſe adheſion of the particles of clay which is neceſſary to conſtitute brick; why it will not vitrify, as lime is an enemy to all vitrification; and why it ſhews a ſmall portion of oleaginous matter, as clay contains ſome oil. By mixing quick or rather effete lime with clay, or a clay ſoil, we imitate, in ſome meaſure, this production of nature, but fall vaſtly ſhort of her in the equality of the mixture, and perhaps to in the ſubtility of the particles.

THERE is a body very ſimilar to marl in its appearance, but very different from it in its effects, and often found in the ſame bed with the beſt marl. It is of a darkiſh lead colour. Inſtead of fertilizing ground, it renders the beſt ſoils incapable of bearing any kind of vegetables for many years. I have ſeen the ſpots on which it was laid entirely barren three years after. I have heard of its effects continuing in other places for a much longer time; nor is it certainly known when its bad effects will end. A body ſo very deſtructive to agriculture, deſerves to be well characteriſed, in order to be ſhunned; and well examined, that we may know whence proceeds this noxious quality, and how to cure it when it has taken place.

THOSE who have been much uſed to marl, have already diſcovered a difference betwixt it and this body. The former, they obſerve, takes a ſmooth poliſh from the inſtruments with which it is wrought, but the latter does not. As this quality alone is ſcarcely ſufficient to diſtinguiſh theſe two bodies from one another, let us apply to experiment for more.

Exp. 25. If a piece of it is taken up which has not been much expoſed to the influence of the air, it differs very much in taſte from marl. Inſtead of the ſmooth unctuous taſte of the latter, it is acid, and remarkably aſtringent.

IT agrees with marl in falling down into a powder in water; but then it differs remarkably from it, in raiſing no afferveſcence with acids, nor in the leaſt deſtroying their acidity.

It turns the ſyrup of violets red; which ſhows, that it contains an acid: whereas marl, like all abſorbent earths, gives it a green colour.

These qualities are ſufficient to teach the farmer how to diſtinguiſh this poiſonous body from marl, and how to ſhun it. Let us now try if we can diſcover on what principles this poiſonous quality depends; for if we can inveſtigate its nature, we may perhaps find out a cure for it. Beſides, all purſuits of this kind lead us directly to the true ſyſtem of vegetation. The vegetable is like the animal body, whoſe nature is aſcertained as well by what does it harm, as by what does it good.

From my experiments in the ſection on till, I imagined that its poiſonous quality might depend on its containing ſome ſalt of ſteel. I, therefore, directed moſt of my trials on this body with that view.

Exp.

Exp. 26. Some of it was infuſed in warm water. The water had a greeniſh colour, taſted gently acid, and very aſtringent. It gave the ſyrup of violets a pale-red colour. *Ol. tart. p. d.* dropt into it made no ſenſible effervefcence, but ſeparated ſome air-bubbles, diſcoloured it, and precipitated a pale-red powder from it. Some of this powder was put into a crucible, and kept in the fire for half an hour. I could recover but little of it again, and that not quite free from the ſubſtance of the crucible; yet the magnet attracted ſome of its particles, and ſhewed that it contained iron. The liquor evaporated gave me a *tartarus vitriolatus.*

THE pure infuſion did not alter its colour much on an admixture of galls. But this was no proof that the liquor did not contain ſalt of ſteel: for an acid deſtroys this effect of the galls; and the liquor, as we have already found, contained an acid. To deſtroy the acid, I poured in *ol. tart.*

p. d.

p. d. into the mixture of the infusion, and galls; it took immediately a brownish colour, and afforded a plentiful precipitation, which, in twenty-four hours, had taken a purple colour.

I boiled a quantity of the earth for half an hour in water, strained and evaporated it. A white saline substance remained in the proportion of 6 grains to each ounce; which tasted exactly like salt of steel. This salt dissolved in water, turned syrup of violets green, as does salt of steel; and took a deep black colour with galls: Sufficient proofs of its being salt of steel. Nor can its white colour be any objection; for salt of steel reduced by trituration, evaporation, &c. to a powder, is white; and the salt which I procured, was a powder.

It appears, then, beyond all doubt, that this substance consists of an earthy body like clay, about an eightieth part of salt of steel, and a small proportion of the

vitriolic

vitriolic acid. From other experiments which I have made, the bad effects do not ſeem to ariſe from the vitriolic acid; eſpecially as the acid here appears to be very volatile. But we have already diſcovered the pernicious quality of ſalt of ſteel. Nor is it any wonder, that it ſhould exert itſelf ſo powerfully here, conſidering the quantity of this body laid on ground inſtead of marl, and the great quantity of this ſalt in it. The ſoil muſt be perfectly ſaturated with it.

But how ſhall we correct the poiſonous quality, if, by miſtake, this or ſuch like bodies ſhould be uſed? For coal produces the ſame effects from the ſame cauſe. There ſeems to be no other method but that of decompoſing the ſalt; ſo that the ſteely part may be no longer diſſolvable in water. The air, by volatilizing the acid, and leaving the chalybeate particles behind, has that effect, by gentle degrees, on ſalt of ſteel, when it is diſſolved in water. But, in the preſent caſe, the acid would not reach the

ſalt,

ſalt, unleſs the ſoil were frequently turned over; and even then much of the ſalt would be defended by the oleaginous particles of the ſoil. Marl appears to me to be the proper cure; for that abſorbent earth, having a ſtronger affinity to the acid of vitriol, than what the iron has, will unite itſelf with the acid, ſeparate the chalybeate particles, render them inſoluble in water, and conſequently unfit to enter the veſſels of plants. A conſiderble ſhare of the good effects of marl in all grounds, may, perhaps, be owing to this ſpecial effect, *viz.* the deſtruction of a body, which, in proportion to its quantity, deſtroys all vegetation.

THERE is another foſſil body very ſimilar to marl in its appearance, and ſome of its qualities, and may be miſtaken for it. It is called by ſome writers ſoap-rock, from its ſimilitude to ſoap, and its being often found in rocks; though I have known it lying on the ſurface in great quan-

quantity. As none has yet analyzed it, we ſhall undertake that taſk.

Exp. 27. It is ſometimes of a bluiſh, ſometimes of a reddiſh colour; and when moiſt, feels exactly like hard ſoap betwixt the fingers.

It falls like marl when put in water: if it is well mixed with the water, it ſeparates into different parts from their different ſpecific gravity; at the bottom there is a layer of large grey particles; above that are ſome darker; next thoſe of a dark brown colour; and the uppermoſt is a light white powder; a great deal of which was ſuſpended in the water for 20 hours.

It efferveſces with none of the acids. In this it differs from marl.

Exp. 28. Some of it was lixiviated in water; which being evaporated, gave a very little ſea ſalt.

Some of it was calcined for four hours in a ſtrong kitchen fire. The bluiſh remained of the ſame colour; but the red turned lighter in its colour. The firſt contained a few particles, which were attracted by the magnet; the laſt almoſt none. It fell as ſoon as the unburnt in water, and with the ſame appearances.

I diſtilled four ounces of it in a ſtrong heat for eight hours, and it gave me only one ounce of pure water.

It did not detonate with nitre in fuſion, but ſome few ſparks appeared, which ſhews that it contains oil.

This oil I extracted, by boiling four ounces of it with two ounces of potaſhes for many hours; to this decoction I added ſpirit of nitre, and got a precipitation of a red heavy oil, which detonated with nitre in fuſion.

I TOOK four ounces of it, and waſhed off the light earthy parts by mixing water often with it; in this way I got ten drachms of a whitiſh powder, which appeared to be clay. The remainder was compoſed of two parts, a fine grey powder, which appeared to be ſand; and ſome large particles, white and green. Theſe did not efferveſce with acids, nor yielded a tincture of ſpirit of wine; but felt ſoft and unctuous in the mouth, and when boiled with ſoap-aſhes, and ſpirit of nitre added to the lixive, afforded a heavy oil. This ſhews them to be of an oily nature.

SOAP-ROCK appears from theſe experiments to contain near a third of clay, a much greater proportion of ſand, and a body of an oily heavy nature.

THAT I might go a little further, and diſcover its effects in vegetation, and with what ſoils it would agree beſt, the following

ing experiment was tried, though late in the year.

Exp. 29. A pot was filled with the pooreſt earth that I could find; this I ſhall call N° 1. N° 2. ſame earth with a third of ſoap-rock. N° 3. very ſtrong clay with a third of ſand. N° 4. the ſame clay with a third of ſoap-rock. N° 5. ſoap-rock alone. In theſe pots I ſowed barley.

The plants ſeemed to grow beſt at firſt in N° 2: but afterwards N° 4. produced the moſt. In N° 5. the plants were longer of appearing, and ſeemed more ſickly than the others.

SECT. IV.

Of unburnt calcarious bodies, and quick-lime.

CHALK is reckoned, by the generality of writers, a good manure for all wet clay grounds; for it makes the earth looſe and hollow; keeps it dry; and, as the farmers expreſs it, ſweetens the ſoil. The ſoft unctuous kind is thought the beſt. Farmers think that it exhauſts the ſoil very much; and therefore they generally adviſe dung to be laid on along with it. Lime-ſtone gravel is much uſed in Ireland as a manure.

THESE calcarious bodies are not diſſolvable in any way but by acids. With theſe a great efferveſcence happens, a ſolution of the calcarious body is made, and a neutral ſalt is formed from that conjunction. This neutral ſalt is always ſoluble in water, unleſs where the acid of vitriol is uſed.

THESE calcarious ſtones, when burnt in a ſtrong fire, turn to quick-lime, a body much uſed in farming. It attracts acids much more than it did before, and is now in a ſmall degree ſoluble in water, without their aſſiſtance. It is not, however, on theſe ſoluble parts that its fructifying power depends;

depends; becauſe it has no ſenſible effect, except in killing vermin the firſt year, when theſe parts are moſt ſoluble in water. Lime is probably effete, and no longer ſoluble, when it begins to act on the ground, and aſſiſt vegetation. The lime of old houſes, which is quite effete, is reckoned better than freſh quick-lime.

THERE is a very great attraction betwixt quick-lime and all oily bodies; it unites intimately with expreſſed oils. With this intention it is uſed in the manufacture of ſoap, to help the junction of the alkaline ſalts and oils. It muſt, therefore, attract the oils powerfully from the air and earth, diſſolve them, and render them miſcible with water: it muſt, from this reaſon, ſoon exhauſt the ſoil of all its oleaginous particles, if the farmer does not take care to ſupply them by dung or animal ſubſtances. Farmers have by experience diſcovered it to be a great impoveriſher of lands, but they did not know how it acted. Its operation is, to exhauſt the earth of its oils, Lime laid on ground wore out by continual crops, rather hurts it than improves it; becauſe it does not meet with oil or oleaginous bodies to act upon, and blunt it. The proper cure for this is, to mix dung with the lime, ſo that it may have ſomething to act on.

Lime is a great diſſolver of all bodies, both vegetable and animal, but particularly the latter. We know how ſoon it diſſolves hair and woollen rags into a pulpy ſubſtance. This effect is ſo ſtrong, that, in the common method of ſpeaking, it is ſaid to burn them. In this way it certainly operates in the earth, by diſſolving all animal and dry vegetable ſubſtances, and converting them to the nouriſhment of vegetables, at leaſt ſooner than otherwiſe they would be.

Lime powerfully reſiſts putrefaction, as is diſcovered by many experiments. It does not appear, therefore, very judicious, to mix quick-

quick-lime with dunghills, which are not yet ſufficiently putrefied, as it muſt ſtop that proceſs. When once that proceſs is finiſhed, many good effects may ariſe from their junction, and particularly that of hindering the oils to be volatilized, and of fixing them.

It is obſerved of lime, that it is continually falling downwards, ſo that, in a few years, the greateſt part of it is to be found lying together as deep as the plough goes. This is owing to its great ſpecific gravity.

It is likewiſe obſerved by farmers, that lime has a better effect on light ſoils than on ſtiff, for the firſt three years, but, after that time, its operation turns much weaker. Light ſoils are moſt pervious to the air; and as the good effects of all manures depend on the influence of the air, that influence muſt be ſtronger in open ſoils than in thoſe which are more compact: but as that ſoil has the looſeſt texture, the lime falls quickly through it.

Besides; by mixing itſelf with the oleaginous particles of the ſoil, and converting them to the nouriſhment of plants, lime becomes in this ſenſe a provocative to the ſoil. In promoting the work of vegetation, it will ſoon exhauſt all the oils of the light ſoils, which contain them but in ſmall quantity, and when they are all extraneous, for ſand can afford none. But a clay ſoil, containing in itſelf a conſiderable quantity of oil, and that not ſo eaſily ſoluble, is not ſoon exhauſted. An addition of an animal or putrefied vegetable ſubſtance to theſe light ſoils, would remedy this defect.

SECT. V.

Of vegetables in an intire and in a corrupted ſtate, and of dunghills.

WE come next to treat of thoſe manures which are drawn from the vegetable kingdom. All vegetables, unleſs ſome noxious ones, nouriſh plants. Malt-duſt is reckoned a good manure. Bark of trees, and ſaw-duſt, are recommended by ſome writers. We learn from *Columella* that the ancients laid the lees of their olive oil on the ground, and found it of great benefit. And, indeed, it is not to be wondered at, that the juices of vegetables already concocted, ſhould prove a nouriſhment to other vegetables. But it requires much time, before theſe can be reduced to ſo ſmall parts, and ſo diſſolved, as to be capable of entering the minute veſſels of plants. This is moſt expeditiouſly and moſt effectually performed by the means of corruption. Hence we may ſee the reaſon, why the

the bun or woody part of flax has no good effect on ground, as the juices are already extracted, by the previous putrefaction which the flax has undergone in the process of steeping, and little now remains but mere earth.

THE different species of sea-weed, especially the kelp, are found very serviceable to land. These weeds are of a soft pulpy texture, and easily dissolve. Besides, there are no plants which contain so much salt, and so much oil, in proportion to their earthy parts. The salts are in such quantity, that the kelp, though very dry, will not burn; as all salts, nitre excepted, are enemies to fire. The oils are discovered to be in great plenty, because this plant, notwithstanding these salts, putrefies very soon. The ashes of this plant * consist of about equal parts of alkaline salt, sea-salt, an oily substance, and an earth.

* Vid. Experiments on bleaching, part 3. sect. 6.

Dung probably was the manure first used by farmers, as all vegetables spontaneously turn to it, and as accident must soon have discovered its good effects. It is the manure at present most used. The manner in which it is made, is, therefore, a speculation worthy of our attention, and may lead to some useful hints in the management of dunghills.

Putrefaction is defined by chymists to be an intestine motion of a body, whereby the union, texture, colour, smell and taste are destroyed.

There is no change so common in nature, as that of bodies from an entire to a corrupted state. All vegetables, whether acid, acescent, alkalescent, austere, aromatic, insipid, cold or hot, are liable to corruption, and generally end in it. The alkalescent, such as onions, celery, *&c.* run immediately into corruption, without undergoing

dergoing the other two fermentations; but the acescent can be made first to ferment into wine, and generally of themselves undergo the acetous fermentation, before they fall into the putrid. Animals are continually in the very confines of putrefaction; and when death stops the circulation and admission of fresh juices, they fall immediately into it. Animals, and alkalescent plants, as they want that acid which abounds in the acescent plants, have a greater tendency to putrefaction, which every one knows is greatly retarded by acids. Next to the excrements, which are already in a state of high putrefaction, the blood is the most putrescible fluid in the whole body; then the urine; and afterwards the solids.

THERE are three circumstances necessary to the process of putrefaction, *viz.* moisture, heat, and the admission of the external air. Moisture is necessary to soften the fibres of plants, that they may be capable of the intestine motion; for we see that dry straw will

will not corrupt. Heat is likewiſe neceſſary, in order to excite and promote that internal motion of the particles which conſtitutes putrefaction. As cold checks this motion, it is a great enemy to all corruption. The admiſſion of the external air is likewiſe neceſſary, as no inteſtine motion can begin without its aſſiſtance. Hence bodies preſerved from the immediate contact of the external air, by being put in an exhauſted receiver, or covered over with greaſe, are kept from corruption.

Besides drineſs, cold, and want of air, there are many other things which reſiſt corruption. But there are no ſpecies of bodies which are ſo much in oppoſition to it as ſalts in general, whether alkaline, neutral, or acid, but particularly the laſt.

The particular ſeat or ſubject of corruption, ſeems to be in the mucilaginous or oily particles; for the more of theſe fat oily particles a body has, it corrupts, *ceteris*

paribus,

paribus, the eaſier. Thus water, replete with the mucilaginous particles of an oozy fat ſoil, corrupts ſooner than water taken from a gravelly ſoil.

The natural progreſs of putrefaction in vegetables is in this way. They begin firſt to heat towards the centre; and emit a ſharp acid ſmell, which is owing to the acetous fermentation. As the heat advances, this ſmell goes off, and is ſucceeded by a very fœtid one. Their colour, if it was light before, now turns dark; and the more the putrefaction advances, the darker is always the colour. They loſe their peculiar diſtinguiſhing taſte, and gain a nauſeous cadaverous one. Their fibres, which had a certain degree of firmneſs, loſe that very ſoon; there is no more coheſion betwixt the minute particles of which they were compoſed, and they fall into a putrid pulp. Theſe are the general circumſtances which attend putrefaction.

If vegetables are examined chymically after putrefaction, they afford principles very different from what they did before it. Their ſalts, which were before fixed, are now become volatile, and their oils are much more volatile and fœtid than what they were. The fœtid ſmell of putrefied bodies is owing to theſe volatile fœtid oils flying continually off. This greater volatility in the ſalts and oils ariſes from their being more attenuated than what they were.

How nature brings about theſe great changes, is difficult to ſay. The moſt plauſible and general theory is, that the minute particles of air, of which there is great plenty incloſed in all bodies, extricating themſelves from the fibres of the vegetable, which is now ſoftened by moiſture, and being agitated by the heat and continual alterations in the preſſure of the atmoſphere, raiſe an inteſtine motion in the

body.

body. This inteſtine motion, cauſing a continual friction betwixt the ſalts, oils, water, and earthy particles of the plant, muſt comminute them, and raiſe a great degree of heat. The oily particles undergo a change from this heat, and acquire a fœtor; and, being joined by the air coming from the putrefied maſs, become more volatile, and affect the ſenſe of ſmelling. The inteſtine motion, it is eaſy to perceive, muſt take away all coheſion in the fibres and particles; and ſo they fall into a pulpy ſubſtance. The oils and ſalts having a natural affinity, will unite; and ſo the ſalts, by the natural volatility of the oil, will become volatile themſelves, from being fixed before.

THIS is a very plauſible theory, though, I muſt own, liable to many objections. The heat and weight of the atmoſphere, muſt reach bodies preſerved by the means of oil, as well as if they were not rubbed with it. We do not find thoſe vegetables which

which are moſt apt to putrefy, contain more air, than thoſe which are leſs liable to putrefaction. The fixed air of vegetables is not acted upon by heat; nor does there appear any cauſe why it ſhould get free. It is difficult to arrive at any degree of certainty in theſe abſtruſe ſpeculations. To me the firſt mover ſeems to be that elementary fire which is incloſed in all bodies, ſet in motion by the external heat of the atmoſphere. Hence the particles are made to recede; and the fixed air uniting, becomes elaſtic, and burſts the veſſels of the vegetable body.

THE deſign and end of this proceſs is more apparent, than the means which the Author of nature takes to accompliſh theſe. Were vegetables 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, carried up into the air, and deſcend again to fructify the earth, which was lately robbed of them. Corruption, then, is the parent of vegetation; and could be ſo in no other way than in the preſent. Though of ſeeming diſadvantage in nature, as ſhewing it on the decay; though highly diſagreeable to the external ſenſes, and often dangerous to health; yet is putrefaction of more uſe than any of the other two fermentations, as it provides for our future nouriſhment, and carries on that beautiful circle, which nature is commanded, by her author and conſtant ſupporter, to move in.

PUTRE-

Putrefied ſubſtances are all of an alkaline nature. The alkaline ſalt is often indeed inviſcated by the oily parts, ſo that it can ſcarcely effervesſce with acids. This has led ſome to aſſert, that putrefied ſubſtances were not alkaline; an aſſertion oppoſite to experiment. We know with what a gentle heat the volatile ſalts of putrefied bodies riſe; a heat incapable to form thoſe ſalts, if they did not pre-exiſt; but capable of raiſing them when once formed. As pigeons dung is the ſtrongeſt of all dungs, for vegetable and animal ſubſtances are the ſame when putrefied, the alkaline ſalts are moſt obſervable in it. I have ſeen the ſurface of that dung covered with a white ſalt, which ſmelt as ſtrong as the volatile ſalt of hartſhorn. Every one is ſenſible of his eyes watering, when he goes into a pigeon-houſe; owing to the pungent volatile ſalts in the air. Subſtances highly putrefied effervesſce with acids. *Reaumur*, ſpeaking of the leaves of the vine, which he had ſet by to putrefy: *Quand elles ont été pourries jusque à ce point on elles perdent leur nommes pour prendre celui de terreau, elles ont fermenté vivement et subitement avec les acides, que je verses dessut. Au lieu que l'esprit de nitre versé sur de fuilles seches, ou sur de fuilles simplement commencé a pourrir, n'ici produit aucune fermentation sensible.* This experiment puts the question beyond all doubt.

FARMERS have discovered, by long experience, that the dung of different animals differs very much, as to the quantity to be used, and the ground upon which it ought to be laid. A much smaller quantity of pigeons dung must be employed than of any other; and even that should be laid on cold wet soil. The dung of sheep and hogs seems, by experience, to have the preference to all others. These different effects depend on the different quantities of oil and volatile salts in the dung; and these again on the food of the animal, on the time it stays in the intestine canal,

canal, on the nature of the juices mixed with the aliment there, and on the natural heat of the body.

Let us now make ſome practical obſervations with regard to the management of dunghills: for this is an affair of conſiderable importance, and in which farmers ſeem to be very ignorant.

Dry vegetables require a conſiderable degree of moiſture before they can be brought to putrefy. I think dunghills are generally kept too dry, as they are commonly in this country placed on a high ſituation, and are themſelves raiſed to a conſiderable height. A hollow ſituation, which will retain the moiſture, is the beſt. Too much moiſture is likewiſe bad. This may be prevented by having hollow places, with clay bottoms, at the ſide of the dunghill, into which the ſuperfluous moiſture may be allowed to run, and from whence it may be reſtored again by pumps to the dunghill at pleaſure.

BUT there is yet a worſe conſequence from ſuch a ſituation. The juices of the dunghill are diſſolvable in water, and are continually waſhed off by the rains which fall. Hence a great part, nay almoſt the whole of the vegetable food, is loſt. It is a bad advice, therefore, which the *Journal Oeconomique* gives, to place the dunghill on a declivity. A hollow ſituation, where the bottom is clay, or where it is cauſeyed, is the propereſt to carry on the proceſs of corruption.

As the ſun and wind exhales the volatile ſalts and oils, and as too much air rather retards this proceſs, I ſhould think it very reaſonable, to place the dunghill in a ſituation ſhadowed and ſurrounded by trees. There is a cloſeneſs and moiſture in this ſituation, which will very much favour corruption.

I ſee that practical farmers adviſe, that the dunghill ſhould be covered with earth,

to

to hinder the volatile particles from flying off. But how can this be done, when there are fresh additions made to the dunghill every day? It would indeed putrefy sooner; but then it must lose the influence of the air, by which only it becomes fit nourishment for vegetables. The effects of the air on the dunghill must be considerable, as it is so loose and pervious a body. I am more inclined to agree with them in another observation, that the north and east winds should have free access, especially in winter, to the dunghill. We shall afterwards see, that these winds are found, by experience, to be more impregnated with the aereal nourishment than the others, and particularly at that time.

As the process of corruption, in the common way, goes on very slowly; and as great part of the dung which is carried out from the dunghill, is not half putrefied, and consequently not sufficiently prepared for vegetables; it would be of use to quicken that process, if we knew of any easy method to do it. There are ferments for the putrefactive fermentation, as well as for the vinous. Hence *Stahl: Corpus in putredine existens, alio a putredine libero facillime corruptionem conciliat; quia illud ipsum, quod in motu intestino jam positum est, alterum quiescens, ad talem motum tamen proclive, in eundem motum intestinum facile abripere potest.*

ANIMAL substances already putrefied, such as stale urine, human dung, the carcases of animals, &c. are the proper putrid ferments. If the urine of horses, and stall-fed cattle, is carried into proper reservoirs, and there allowed to turn stale, it will, if thrown on the dunghill, very much quicken the fermentation.

PUTREFIED bodies are of a very volatile nature; insomuch that if exposed to a dry hot air, they continually diminish in bulk, until all the volatile parts being carried off, the remainder is found to be an

earth

earth moſtly of the abſorbent kind. This ſhows, that dunghills ſhould not be kept too long after they are ſufficiently putrefied; and that dung ſhould not be expoſed on the ſurface of the ground in hot weather, as often happens; but immediately ploughed in, if carried out at that time. It is aſſerted by ſome farmers of obſervation, that dung, when expoſed for five or ſix weeks on the ſurface, fructifies ground more, than when it is directly ploughed in, and mixed with the ſoil. If this obſervation is found to be true, the winter and ſpring will be the propereſt ſeaſons for expoſing it. A ſuperficial ploughing after the dung is ſpread, would ſeem to bid faireſt for attaining the advantages and ſhunning the diſadvantages of both methods.

The mud of ponds and ditches comes properly under the claſs of putrefied bodies, as it conſiſts of earth and the putrefied parts of vegetables.

SECT. VI.

Of manures which arise from burning vegetables.

ALL vegetables converted into aſhes by the action of the fire, afford a good nouriſhment for vegetables, eſpecially for graſs; becauſe, as their action is very ſudden, it is ſooner obſervable on a graſs than corn field. Chymiſtry ſhows, that theſe aſhes conſiſt of an indiſſolvable earth, and an alkaline ſalt; which latter body attracts acids more ſtrongly than any other. Fern aſhes contain the moſt ſalt of any common vegetable which I know; the ſixth part is alkaline ſalt. They muſt, therefore, be the propereſt for this uſe. At the alum works near *Scarborough*, the farmer pays 2 *s.* a cart-load for the refuſe of the earth of theſe aſhes, after almoſt all the ſalt is extracted out of them. The refuſe of the ſoap manufactures, and of the bleachfield, are rich manures. The aſhes

ashes of peat, which are most used, afford salts equal only to the thirty-second part of the whole, and are the weakest of all those I know.

HERE we must class the burning of the turf, or surface, which is often done to improve poor soil. Farmers think it acts by dispelling a sour juice which land has contracted from lying long untilled: and they chiefly prescribe it for that sort of poor ground; for they all agree that it hurts rich soil. But I imagine, that the benefit arising from it is owing to the alkaline salt arising from burning the roots of vegetables: for farmers enjoin us to go no deeper than those roots; and it is found, that the greater the quantity of roots, as happens in land which has been long untilled, the more benefit arises from burning.

THERE is another manure which takes its rise from fire, and properly belongs to this

this ſection; that is, ſoot. This is found, by chymical experiments, to be a compoſition of volatile alkaline ſalt, oil, and a little earth. It is remarked, that the effects of this compoſt are very ſudden, they being obſervable after the firſt rains.

SECT. VII.

Of animal manures.

ALL animal ſubſtances enrich ground prodigiouſly; ſuch as, blood, garbage, urine, *&c.* becauſe they putrefy eaſily. As we have treated of dung, we need not ſpeak of theſe. But there are other animal ſubſtances, ſuch as ſhavings and tips of horns, hair, ſilk, woollen rags, *&c.* which do not ſeem, from their firm texture, to be ſo capable of putrefaction. All theſe contain a great quantity of a mucilaginous and gelatinous ſubſtance, capable of being diſſolved by water, of a ſaponaceous nature, and conſiſting, as appears by chymical experiments, of ſalts and oils intimately

intimately mixed, and diſſolved in much water. This mucilaginous ſubſtance muſt, then, be fit nouriſhment for plants.

The action of theſe manures is commonly attributed to their imbibing the dews, and conveying moiſture to the ground. But woollen rags rather repel, from their oily nature, than attract moiſture; and were they only ſimply to conduct the moiſture into the ground, linen rags would do as well: but they do not. Theſe woollen rags being much uſed in chalky grounds, which are dry, has given riſe to this opinion. What theſe grounds ſtand moſt in need of, is a mucilaginous ſubſtance, which theſe rags are full of.

The animal ſhells, ſuch as oyſter-ſhells, periwinkles, cockles, &c. muſt be included amongſt animal ſubſtances. Theſe are long of diſſolving; but it is obſerved, that in ſix or ſeven years they make the ground ſo mellow, that it muſt be allowed to ſtand a year or two, that it may conſolidate again, and the ferment be reſtrained; elſe it is not able to ſupport the corn. The reaſon of this expanſion of the earth, will appear from the expanſive force of ſhell-marl. Theſe different ſhells are a compoſition of calcarious particles, fit to be converted, by the fire, into quick-lime, and of an animal oil.

We muſt here conſider a body, called *ſhell-marl*, which is commonly, though improperly, claſſed with the marls. It muſt be ranked amongſt the ſhells, as it is a putrefied animal ſhell. It is a white light ſubſtance, with an odorous ſmell, appearing to the eye to conſiſt of a number of ſmall ſhells, and generally found at the depth of a foot or two in thoſe hollow grounds which have been formerly overflowed. An animal inhabiting ſuch a ſhell I have met with in ponds, though it is very rare. It muſt have been once a very common creature in this country, and appears

pears to have been deftroyed in moft counties at once by fome general difafter which affected it; the natural depofition of foil from thefe waters has buried it fo deep.

Exp. 30. When water is poured on this body, it fucks it in greedily, and fwells like a fpunge; becomes very foft, but does not fall down like marl into a powder. It is by means of this quality that all fhells, whether they are laid on corrupted, or become fo in the foil, make ground fo very light and fpungy.

I could difcover no falt in it, by the different trials which I made. It makes a ftrong effervefcence with acids, and requires fix times more of them to faturate it, than what any of the marls which I have yet met with do.

It affords on diftillation, like all animal fubftances, a urinous alkaline fpirit, and an oil of the heavy kind.

WHEN

When calcined in the fire, it is converted to quick-lime. By theſe experiments it does appear plainly to be a putrefied animal ſhell, eaſily ſeparable by water, and a ſtrong attracter of acids.

PART

PART III.

SECT. I.

The effects of different ſubſtances with regard to vegetation.

THOSE manures which I have examined, are ſuch as chance diſcovered to be uſeful in vegetation, and practice has continued, becauſe they can be eaſily and cheaply got. But, for what we know, there may be others, which, though not in ſuch plenty as to be of uſe to the farmer, may have effects on vegetation, that may be uſeful to thoſe who inquire into the nature of the vegetable food. The more they know of the effects of different bodies on plants, the greater chance they have to diſcover the nouriſhment of plants; at leaſt this is the only road. I made the following experiment with this deſign.

Exp. 31. *May* 2. 1755, I took ſome virgin earth from the ſide of a ſteep bank, where neither dung nor plough had ever been; filled ſome pots with it; mixed with the earth the following materials; and ſet them in the ground. Each pot contained about 6lb. of earth. In each pot I planted five grains of the ſame barley; and that I might be ſure that each grain was proper for ſeed, I took none but what fell to the bottom of water. N° 1. contained plain virgin earth, that I might have a ſtandard for the reſt. N° 2. was always watered with hard water. N° 3. had 1 oz. of ſaltpetre, and 2 oz. of oil of olives, mixed with the earth. N° 4. contained 1 oz. of ſaltpetre. N° 5. contained half an oz. of vitriolated tartar. N° 6. contained 1 oz. of flour of brimſtone. N° 7. contained half an oz. of ſpirit of hartſhorn. N° 8. contained 2 oz. of oil of olives. N° 9. contained ſpirit of nitre, diluted with water, half an oz. N° 10. con-

contained of sea-salt 1 oz. N° 11. contained plain earth, and the grains steeped for 16 hours in a strong lye of hens dung and saltpetre.

May 9. when I looked at them again, N° 1. and 2. had each one plant, just appearing above ground. N° 6. had two taller than the former. N° 8. had all the five up, one of which was three fourths of an inch tall.

May 11. N° 1. has all five up, and about half an inch high. N° 2. has two, and as high. N° 3. 4. and 5. have one each, just appearing. N° 6. has four, three fourths of an inch tall. N° 7. has one, half an inch tall. N° 8. has five, one inch tall. N° 9. has two, just appearing. N° 10. has none. N° 11. has four. Some of the same grain set in the garden-mould just beside the pots, were three fourths of an inch high.

May 21. five or ſix days rain, and then fair weather. N° 1. and 2. have five, about four inches tall. N° 3. has four, three inches tall. N° 4. has five, about two inches tall. Thoſe in N° 5. are three inches tall. N° 6. has five equal to N° 1. and 2. N° 7. has two, about one inch. N° 8. has ſix, two and a half inches tall. N° 9. has three, above half an inch tall, and very ill coloured. N° 10. has one, half an inch tall. N° 11. has five, which are the beſt of all.

June 1. N° 2. the beſt of all, nine inches high, and of the deepeſt green. N° 12. contained the next for ſize and colour, and was but little inferior. N° 6. next in height, but had many withered leaves; N° 3. 4. and 5. about five inches tall, and of much the ſame colour; N° 7. about an inch tall, with ſome of the leaves withered; N° 8. high, but ſomewhat withered; N° 10. has three about an inch long.

June

June 10. N° 2. ſtill beſt. N° 6. almoſt withered. N° 7. entirely withered. N° 9. and 10. contained poor ſickly plants.

June 18. N° 2. ſtill beſt, and has nineteen ſtalks. N° 12. next, and has ten ſtalks. N° 1. not quite ſo tall, but has thirteen ſtalks. N° 3. comes next. N° 6. almoſt quite gone. N° 7. none. N° 8. and 9. equal. N° 10. leaſt of all.

Aug. 16. N° 1. has ſeventeen ears of corn. N° 2. has nineteen. N° 3. has thirteen. N° 4. has fifteen. N° 5. has twenty-nine. N° 8. has nine, and thoſe very large. N° 9. has twenty, and thoſe large. N° 10. has ſtalks about a foot in length, and four or five ears, about one inch long only. N° 11. has eighteen very good ones.

Thus I have related the experiment faithfully and minutely, as becomes every experimenter. The facts ſhould always be related by themſelves, diſtinct from all reaſoning; for we may err in the latter, but the former is truth itſelf. I ſhould have been glad to have repeated theſe experiments, eſpecially with a poorer ſoil than what I found, by experiment, this to be. I ſhould have been glad to have had a greater fund of experiments to have reaſoned upon, as there is always danger of ſome miſtake in reaſoning from a ſingle experiment. But it is to be remembered, that ſuch experiments can be made only once a-year, and there is no time left now to repeat and augment them. As it then ſtands, I ſhall draw ſome concluſions from it.

Corollary 1. Virgin earth, taken up within a foot of the ſurface, and from a bank which had a north aſpect, contains in itſelf the principles of vegetation in great plenty. Such earth is uſed as a manure by farmers; and they obſerve, that virgin ſoil will fructify earth much richer in appearance than itſelf.

Cor.

Cor. 2. Grain appears to grow better, that it has been steeped in dung and salt-petre. It is a fact long ago observed, that grain vegetates stronger, quicker, and is less subject to blight and mildew, if it has been steeped in liquors which contain salt and oil, such as sea-water, stale urine, *&c.* This is easily accounted for. It is certainly of great moment, with what the vessels of the seed are at first filled, whether with watery or with rich juices. This is one great reason that makes a dry seed-time so useful: for if the ground is dry, the juices which the seed imbibes, are rich and nutritious; whereas in rainy weather, these juices are diluted with too much rain, and the tender plant is weakened. In medicating grains, we fill their vessels with plenty of salts and oils, and give them vigour to send out many roots, upon which the nourishment of plants depends. The way to make a strong man, is to nourish the child with suitable food.

Cor. 3. Hard water appears to afford a ſtrong nouriſhment for plants. This is very oppoſite to the common received opinion: for gardeners never uſe it, when they can get ſoft water; and if they ſuſpect any hardneſs, endeavour to ſoften it as much as they can, by letting it ſtand expoſed for ſome time to the heat of the ſun. In this, however, they are miſtaken. This expoſition may make water harder; but can never ſoften water which is conſiderably hard. The hardneſs of this water which I uſed, and indeed of all hard waters * which I have met with, was diſcovered, by experiments, to be owing to the acid of nitre, joined to an abſorbent earthy baſe. The baſe in this water was a calcarious earth; in moſt hard waters it is only an abſorbent.

Cor. 4. Oil of olives, in the proportion

* *Vid.* Experiments on bleaching, ſect. on hard waters.

of 1 oz. to 3 lb. of earth, appeared to have very good effects at firft; but thefe afterwards declined. The ears were good, though not many. Was the oil in too great quantity? Was it not fufficiently attenuated by the falts in the earth; and, by that means, did it not block up the mouths of the radical veffels? Had it not fufficient time to incorporate with the earth? Thefe are queftions which I cannot refolve.

Cor. 5. It appears, that faltpetre, in the proportion of 1 oz. to 6 lb. of earth, rather retarded than promoted vegetation. This indeed furprifed me, as I generally believed nitre to be of a very fruitful nature; nay, the very caufe of fertility. It does not feem to have been employed in too great quantity neither. Its great reputation for fertility would make one cautious in doubting that effect, without a fufficient number of experiments to fupport that opinion.

Cor.

Cor. 6. The vegetative effects of nitre does not ſeem to have been increaſed by the addition of twice its quantity of oil of olives. The oil of olives ſeems to have ſucceeded better with the addition of the nitre than without it. The ſalts would attenuate the oil, and help it to enter the veſſels of the plant more eaſily.

Cor. 7. Vitriolated tartar, which is a compoſition of the acid of vitriol and an alkaline ſalt, ſeems to promote vegetation very ſtrongly. A gentleman wanted to deſtroy ſome rank graſs in his court, and was adviſed to ſprinkle it with the oil of vitriol, as the greateſt enemy to vegetation. He did ſo; but, to his great ſurpriſe, the graſs came up much ſtronger than before.

Cor. 8. Sea-ſalt, in the proportion of 1 oz. to 6 lb. of earth, appears to be an enemy to vegetation. Moſt farmers commend it as a good manure, though there

are

are ſome who doubt of its good effects. Perhaps in a ſmaller quantity, its effects may be more beneficial; eſpecially if it contains the bittern, which is a compoſition of the vitriolic acid, and an abſorbent baſe, and a bituminous oil, both of which muſt be aſſiſtants of vegetation. The ſalt which I uſed being table-ſalt, was in a great meaſure freed from theſe.

Cor. 9. The acid of nitre ſeems to have retarded vegetation at firſt; perhaps from its being not ſufficiently united to the abſorbent particles of the ſoil. But at laſt it ſeems to have promoted the growth of the plants conſiderably.

Cor. 10. Spirit of hartſhorn, which is a volatile ſalt diluted with water, ſeems to have poiſoned the young plants.

Cor. 11. Flowers of brimſtone, 1 oz. to 6 lb. of earth, appears to have promoted vegetation greatly at firſt; but in a month's

time

time to have deſtroyed the plants like a poiſon. This ſubſtance is often ſprinkled on turnip-ſeed before it is ſowed; and it is thought by farmers to aſſiſt their growth, and to keep the flies from the leaves. Was too great a quantity of it uſed in this experiment? Plants, therefore, have not only their food, but their poiſon. *Quær.* Will the artificial ſulphur, which ariſes from the combuſtion of many plants in a particular way, and which is to be found in great plenty in kelp-aſhes, in the ſoap-aſhes, and in many of the aſhes uſed in the bleach-field, have the ſame bad effects as natural ſulphur?

After the laſt experiment was made, there appeared to me a conſiderable difference betwixt the method by which it was carried on, and the courſe which nature follows in ſuch operations. I mixed the materials, whoſe effects on vegetation I wanted to diſcover, all at once with the earth: but in a natural way, the fructifying prin-

principles muſt be beſtowed on it by gentle degrees, and in very ſmall quantities. Earth, indeed, which has lain for ſome time fallowed, and is therefore well ſtored with the ſeeds of vegetation, is much in the ſame ſtate with the earth of my experiments, though not ſo much ſaturated with the nutritive principles, as mine was with the different materials. Beſides, the former is conſtantly receiving freſh ſupplies. That I might approach nearer to the courſe of nature, and ſupply materials according to the growth of the plants, the following experiments were made.

Exp. 32. Six pots were filled with poor, light, virgin earth. Each pot contained 5 lb. and 5 grains of heavy barley. N° 1. had no mixture. N° 2. was watered with 1 dr. of ſaltpetre diſſolved in 3 oz. of water. N° 3. with the ſame quantity of ſea-ſalt. N°. 4. with the ſame of Epſom ſalt, which is compoſed of the acid of vitriol, and the earth, called *magneſia alba.* N° 5. with 2 dr.

dr. of the following compoſition diluted in water. Half an oz. of quick-lime was ſaturated with weak ſpirit of nitre, which produces a very cauſtic liquor. N° 6. with 2 dr. of the former mixture, having half its quantity of oil of olives mixed with it. This compoſition appeared to me to approach near to the natural vegetable food. All the ſeeds were ſown *June* 16. 1756, except N° 6. which was not till the 19th of *June*. I planted ſome of the ſame ſeeds in the garden-mould beſide the pots.

June 23. N° 1. has one plant, half an inch high. N° 2. has one, an inch tall, and another, juſt appearing. N° 3. none. N° 4. has four, two of which are one inch tall. N° 5. none. N° 6. has three, one inch tall.

June 27. N° 1. has four, two and an half inches high. N° 2. has four. N° 3. has two, the talleſt is an inch high. N° 4. has five, two inches. N° 5. none. N° 6. has

has four as tall as N° 4. Thofe in the rich garden foil were three and an half inches tall.

July 4. N° 2. taller and greener then N° 1. N° 4. and 6. equal to N° 1.

July 10. N° 2. beft. N° 6. next. No. 4. next. N° 1. and 3. follow. N° 5. has one, three inches high.

July 15. N° 1. four of the five plants have yellow withered leaves. N° 2. and 6. deepeft coloured and talleft. N° 3. and 4. equal. N° 5. has one weak plant, about fix inches high. The weather has been hot for ten days. Added to N° 2. 3. and 4. 1 dr. more of each of their falts, and to N° 5. and 6. the fame quantities of the fame mixtures.

July 24. has rained five days. N° 2. and 6. about fifteen inches tall, and much better than the reft; the latter rather beft.

N°

N° 4. next beſt, and twelve inches tall. N° 3. next, and nine inches. N° 1. next. N° 5. has one, about twelve inches. Thoſe in the garden ſoil near two feet, and have ſent up many more ſtalks.

Auguſt 19. The laſt fortnight cold rainy weather, with eaſterly winds. N° 6. is the talleſt, of the deepeſt green colour, and therefore the beſt. The reſt as formerly. Added to each the ſame quantity of ſalts and mixtures as before.

September 1. Has been good warm weather. The plants as before.

September 26. N° 1. had ten ears, the largeſt of which carried twenty grains. N° 2. has eleven, the largeſt of which had twenty-four grains. N° 3. worſe than N° 1. N° 4. has thirteen ears, the largeſt of which carries twenty grains. N° 5. has but one ear; and that is not ſo ripe, and has ſmaller grains than the reſt. N° 6. has

has ſixteen ears, many of which carry twenty-four grains, and thoſe larger than any of the reſt. It has one double ear, which has forty grains. Many of the ears in the garden ſoil have thirty-two grains.

LET us now draw ſome corollaries from this experiment.

Cor. 1. Sea-ſalt added in ſmall quantities, and by gentle degrees, to a poor ſoil, ſeems again to be rather hurtful than beneficial to it. What effect it would have on a ſoil full of oleaginous particles, appears not from this experiment,

Cor. 2. Saltpetre managed the ſame way, promotes vegetation conſiderably, and appears to have made the ſoil capable of producing a fourth more.

Cor. 3. Epſom ſalt applied the ſame way, is pretty nearly equal in its nutritive power to ſaltpetre. The foregoing experiment taught me the good effects of the acid of vitriol ſaturated with an alkaline ſalt; the preſent teaches me, that the ſame acid ſaturated with a particular abſorbent earth, promotes fertility. Hence I concluded, in part 2. ſect. 3. that marl added to the ſame acid, after the poiſonous chalybeate particles were ſeparated from it, would rather be of ſervice than diſſervice to the ſoil.

Cor. 4. Quick-lime, ſaturated with ſpirit of nitre, added in ſmall quantities, and well diluted with water, appears to have hurt the vegetative power of the ſoil. Was it uſed in too great quantity? or did it not meet with what is as neceſſary to vegetation as itſelf, a due proportion of oleaginous particles, which nature always ſupplies in proportion as ſhe ſupplies the ſalts? The latter ſeems to have been the caſe, from the following corollary.

Cor.

Cor. 5. The former liquor, with half its quantity of oil of olives added to it, and ſhaked well together, appears to have enriched the ſoil moſt, and to have nearly doubled its fertility.

Cor. 6. None of our admixtures was able to bring the poor light ſoil to the ſame fertility with the rich garden mould. And no wonder. There the ſalts and oils are highly attenuated, duly proportioned, and well mixed, by length of time; and, conſequently, fitted to enter the ſmall veſſels of the roots. Beſides, that ſoil, by the mixture of putreſcent matter, is in a conſtant ſtate of fermentation, becomes eaſily penetrable, and offers a larger field for the roots of plants to feed on.

As lime never acts on the ſoil till it becomes effete, I was willing to ſee its effects when ſaturated in that ſtate with the acid of nitre; although experiments ſeem to ſhow, that the product is much of the ſame nature. Half an oz. of old lime wall, was therefore ſaturated with the ſpirit of nitre.

Exp. 33. *July* 15, 1756, two pots were filled with the ſame earth as uſed in the former experiment, and in the ſame quantity. Three grains of barley were ſown in each pot. N° 1. contained plain earth. N° 2. was watered with 1 dr. of the ſolution well diluted.

July 25. N° 1. has three plants, one inch in height. N° 2. has one, the ſame height.

Aug, 19. N° 2. has only one; but that is of a deeper green than any in N° 1. Added to N° 2. the ſame quantity of mixture as before.

Sept. 26. N° 2. of a deeper green, has more after-ſhoots, and a longer ear than any in N° 1.

Cor.

Cor. I can hardly ſay whether the ſoil was the better or the worſe for the mixture: for, on one hand, only one of the ſeeds took effect; and on the other, that plant was in a more thriving ſtate than any plant in the plain earth. This, however, appears plain, that it had not the bad effects of the ſpirit of nitre and quick-lime in the former experiment. Was this owing to the lime being quick in the former, and effete in the latter caſe? or to a ſmaller quantity of the mixture being uſed? I rather incline to the latter opinion, as the mixtures appear to be ſimilar by experiment.

THAT I might diſcover the effects of the ſame ſolution on rich garden mould,

Exp. 34. *July* 14, 1756, I filled two pots with 5 lb. each of that ſoil; ſowed four grains of barley in each, and watered N° 1. with the ſame quantity of the ſame ſolution uſed in the foregoing experiment. *July* 20. three plants have appeared in each pot; thoſe in N° 2. a degree taller than thoſe in N° 1. *July* 27. the plants in both pots equal. *Aug.* 13. the plants in N° 1. are rather taller than thoſe in N° 2.: but none of them thrive well; either becauſe they were late ſown, or becauſe they were in a corner where two tall hedges met, and therefore wanted air. I removed the pots to a more open place. *Sept.* 1. N° 1. has one taller, and of a deeper green, than N° 2. The plants have grown faſter than before. *Sept.* 30. the plants are come to no perfection.

Cor. 1. The plants in the two laſt experiments did not vegetate near ſo quickly in the ſame time, as thoſe of the preceding experiment had done. Has not the ſpring, from ſome particular cauſes which operate at that time, a peculiar vegetative power, which the ſummer poſſeſſes not in ſo great a degree? So it appeared to me, although the ſummer was cold and rainy, like our ſprings, and the ſoil in the latter experiment

ment very rich, and in the former taken from the ſame place that the earth of the foregoing was.

Cor. 2. Plants ſeem to ſtand in need of a conſtant application of free air to their ſurfaces. All trees in thickets ſtretch out their branches either laterally or longitudinally, where they can have moſt air. Does this air act only on their ſurface? or does it enter the veſſels of the plant? If the latter, is not an *impetus* from the air in motion neceſſary in order to its entrance, as the mere preſſure of the air is always the ſame in ſimilar altitudes?

Cor. 3. The plants ſeem neither to have been much better, nor much worſe, for the addition of the ſaline mixture.

Exp. 35. *May* 25, 1758, I ſowed ſome barley in 4 different pots, filled with the ſame poor earth. N° 1. contains the pure earth. N° 2. the ſame earth frequently watered with a ſolution of that particular ſalt found ſticking on the plaiſtered walls of boghouſes, *&c.* It got altogether 1 dr. of this ſalt. N° 3. ſame earth watered in the ſame way with the ſame quantity of crude tartar, which was the only eſſential ſalt that I could get at the time. N° 4. the ſame earth treated the ſame way with the ſame quantity of ſoluble tartar, which is the former acid ſalt neutralized with an alkaline ſalt.

June 10. All pretty equal. *July* 25. N° 1. has two ears, and the worſt of all. N° 2. has ſeven, all larger. N° 3. has five, very good. N° 4. has three.

Auguſt 8. N° 1. has nine. N° 2. has fourteen. N° 3. has nine. N° 4. has fifteen.

22. N° 4. has the heavieſt ears, and ſtrongeſt ſtraw. N° 2. is next to it. N° 3. is better than N° 1.

Cor.

Cor. 1. The aereal nitre promotes vegetation very much. This salt we elsewhere prove to be the fossil alkali.

Cor. 2. The essential salt of rhenish wine promoted vegetation a little. The same salt neutralized, had very strong effects on the growth of plants.

That I might discover the natural effects of rain-water,

Exp. 36. *May* 23, 1758, I took two pots filled with poor earth, sowed some barley in each, and placed them near the window of a green-house, so that they might get air, but no rain. N° 1. was constantly watered with spring-water. N° 2. with the same quantity of rain-water.

June 10. The plants watered with rain-water, seem the best; but those of both pots appeared sickly for want of a sufficient quantity of air.

Aug.

Aug. 2. The rain-water appears ſtill beſt. 22. I cannot ſay which is beſt, as they are both ſo ſickly.

These are all the experiments which I have made with regard to the effects of different bodies on vegetation. This field has not been cultivated with that attention which the merit and importance of the ſubject requires. It is indeed extenſive, as it takes in the operations of all bodies which can be either diſſolved or attenuated, ſo as to enter the veſſels of plants. But it is only from a number and variety of trials made in it, that we can expect to ſee a juſt theory of vegetation ariſe. I could wiſh, before I attempt that ſubject, to be poſſeſſed of a greater number, and thoſe oftener repeated, that my concluſions might have been more general and more certain. They were ſuch as appeared to me to reſult naturally from the experiment. How far they are to claim aſſent, I have left in every one's power to judge.

SECT.

SECT. II.

Of the food of vegetables.

WE now come to treat of that important question, What is the food or nourishment of plants? a question which has been much handled, but not sufficiently ascertained yet. It has even been made a question, Whether each plant has not its peculiar and proper food, which it chuses amongst the rest, from some elective power inherent in its roots?

THOSE who take this side of the question, assert, that the advantage arising from the change of species is a certain proof of this; for if the same nourishment served all grains, the same grain would thrive in the same ground, as well as another; that although wheat will not succeed in the same ground for two years successively, yet it will bear another grain very well; and that the different nature and properties of vege-

vegetable juices are a ſtrong proof on their ſide.

Those who aſſert, that all vegetables feed on the ſame food, ſupport their opinion by the following arguments. The longer ground is kept in tillage, though it bears grain of different ſpecies, the worſe it becomes: but this would not happen, if plants took different particles from the ſoil: That all ſort of weeds ſtarve corn, by taking part of the ſame nouriſhment: That fallowing ground would be an uſeleſs practice, ſince there is ſuch a diverſity of ſpecies: That it would be in vain for plants to have a taſte, ſince they have no local motion: That change of ſpecies ſucceeds, not becauſe plants take only their own food, but becauſe ſome looſen, while others bind the ground; ſome roots go deep into the ground, while others keep about the ſurface: That it is true, wheat will not ſucceed in the ſame ground two years ſucceſſively, becauſe it requires more food than that

that ground can afford, although there is ſufficient nouriſhment left for other grains; and there would be no time left to plough the ground, as wheat is ſown in the harveſt: and, That the difference of vegetable juices depends not on the difference of food, but on the particular ſtructure of the veſſels of plants.

The latter opinion muſt appear to every one to be nearer the truth than the former: nearer the truth, I ſay, becauſe the advocates for it ſeem to think, that one ſort of food ſerves all vegetables. There I differ from them. We ſaw, by the experiments in the laſt ſection, that the ſalt of hard water, Epſom ſalt, and the vitriolated tartar, ſalts very different from one another, nouriſhed vegetables of the ſame ſpecies; and therefore the food is not of one kind. We know that ſome trees contain the acid of vitriol, becauſe with their charcoal we can make a ſulphur. We know, likewiſe, that ſome plants contain a nitrous ſalt,

while

while others one like ſea-ſalt. Some vegetables require a greater proportion of watery parts, and ſome a ſmaller. The food of vegetables, then, is not all of the ſame kind. See a Treatise of Agriculture Edinb. 176 p. 34 —

THALES maintained, that all things were made from water.

HELMONT was of this opinion, and ſupported it by an experiment known to every perſon. He planted a willow, weighing 5 lb. in a pot filled with dry earth. The earth he watered with rain-water. In five years the willow, not computing the leaves which had fallen off, weighed 164 lb.; but the earth had loſt nothing. That elementary water is the food of vegetables, is a concluſion too ſtrong from this experiment. It only ſhows, that water contains particles which are capable of nouriſhing plants. We have ſhown, that ſnow and rain-water contain earth, oil, and as they ſweep the air, muſt contain ſuch ſalts as are in it too.

SOME

SOME modern philoſophical chymiſts, ſuch as Meſſ. *Eller* and *Euler*, are of opinion, that water is the nouriſhment of plants. The latter found that onions and ſome branches grew in diſtilled water. But the experiment does not convince me, for diſtilled water, as well as rain-water, contains ſalts and oils. He owns in the ſame paper, that the diſtilled water, expoſed to the ſun, recovered its ſalts, oils, and earth. It will, then, recover the ſame principles when the plants grow in it. It is not neceſſary here to enter into that nice diſcuſſion, whether water receives theſe principles from the air, which I think moſt probable, or is converted into them, which is his opinion; it is ſufficient for my purpoſe to ſhow, that theſe principles enter the veſſels of the plants along with the water. As I know no experiment that eſtabliſhes this opinion, it appears to ſtand in oppoſition to all my experiments: for ſome ſalts have ſtrong vegetative powers; but

but theſe do not ariſe from attracting and retaining moiſture, as theſe powers do not appear to be in proportion to that quality.

Others think, that the more terrene particles are thoſe which nouriſh plants. Of this opinion is the famous *Tull*; becauſe, ſays he, earth augments them; and whatſoever augments them, muſt be their food. Dung, and other manures, act only by fermenting, and ſo attenuating the ſoil; and are of no more uſe, than, as a knife, to divide their food. But earth alone could never do, without ſome more active principles. Had *Tull* been a chymiſt, he would have known, that mere earth makes but a ſmall part of all plants. Soil may certainly be too looſe. To earth already ſufficiently attenuated, manures would do no ſervice. Whence the ſalts and oils of plants? Theſe are objections which the favourers of his ſyſtem never can anſwer.

Others

Others, ſeeing the neceſſity of the air to all plants, and obſerving that plants imbibe a great deal during the night, as Dr. *Hales*'s experiments ſufficiently ſhow, aſſert, that the ſoil only gives them ſupport, but air nouriſhment. To this the anſwer is ſhort, That plants thriving better in ſome ſoils than in others, and in proportion as theſe ſoils are manured, ſhows the ground to be the principal paſture of plants; the air being the ſame in grounds adjoining to one another.

The author of the *Hiſtoire Phyſique* deduces all plants from certain ſimilar organiſed parts, which he ſuppoſes flying up and down the air in great plenty, and which attach themſelves, in ſome unknown way, each to its own tribe. If this were the caſe, dung made of plants of the ſame ſpecies, would ſucceed beſt; which is not ſo. I ſhall allow this unphiloſophical opinion to fall of itſelf, as it muſt naturally do, when unſupported by experiments.

OTHERS attribute vegetation to ſalts of different kinds. But whence they come, and of what nature they are, we have only their own aſſertion.

IT is the common fate, in all diſputed points, that each attaches himſelf to one ſide, without allowing the other any ſhare of truth. I have found by experience, that each ſide has generally ſome truth in it; that mankind err by extending that particular truth to a general one; and that the real truth is generally made up of ſomewhat taken from each opinion. The reaſoners on agriculture have failed, becauſe they aſſerted, that plants were fed either by air, water, earth, or ſalt. I join, in ſome meaſure, with all theſe; and aſſert, that plants are nourished by theſe bodies, united with two others, oil and† fire in a fixed ſtate. Theſe ſix principles joined together, in

† Fire is comprehended in Oil. See a Treatise of Agriculture — Edinb. 1762 p. 21.

in my opinion, conſtitute the vegetable nouriſhment. ×

This eaſily appears, when we conſider, 1. That ſeveral kinds of nouriſhment, ſuch as leather, hair, horn-ſhavings, rags, and all vegetables, and vegetable juices, in an intire ſtate, prove proper food for vegetables. 2. That all vegetables and vegetable juices afford thoſe very principles, and no other, by all the chymical experiments which have yet been made on them with or without fire. More arguments could be brought; but theſe two I think concluſive.

Air active and fixed is to be had every where, if we are not at much pains to exclude it. Elementary fire is to be found in all bodies. Earth may be ſupplied by any ſoil managed with proper care. Water drops from the clouds. Oil is a natural principle of all earth, deſcends with the rains and ſnows, and is communicated to the ground by all the vegetable and animal manures, in a ſound or putrid ſtate, as our experiments have ſhewn. But whence the ſalt, the moſt active, and, therefore, moſt neceſſary principle of all? We have not as yet diſcovered any in rich ſoil, nor in the manures moſt uſed, *viz.* lime, marl, ſhells, chalk, *&c.* This is an important queſtion; opens up the action of almoſt all manures, and of rich ſoils; ſhows wherein the effect of the air conſiſts; and, therefore, deſerves a particular diſcuſſion.

The preceding experiments have ſhown, that all fertile ſoils, and all manures, except thoſe already converted into a mucilaginous nature, conſiſt of particles, which, in part, or all together, attract acids. Dung, the aſhes of vegetables, burnt earth, contain ſuch particles; lime, marl, animal ſhells, chalk, *&c.* are wholly of this nature. Theſe then muſt attract and retain all acids, when they come within the ſphere of their attraction. If the air, to which the ſoil is continually expoſed, contains any acids,

acids, theſe bodies will draw it out, and be converted to a neutral ſaline ſubſtance, enjoying the properties of ſalt, ſuch as ſolubility in water, diſſolving oils, and rendering them miſcible with water. Nothing, then, remains to be proved, in order to the converſion of theſe manures into a ſalt, but that the air contains an acid ſalt.

THIS has been the opinion of the greateſt chymiſts, not from theory alone, but becauſe they diſcovered, that alkaline ſalts, when expoſed to the air, were converted into neutral ones; and that metals, ſuch as tin, copper, and lead, were corroded, and converted to a ſalt. Whether there is ſuch a ſalt, and what its nature, will be beſt aſcertained and illuſtrated, by conſidering the manufacture of nitre. This proceſs too will ſhow the operation of the different manures, as theſe are the very materials uſed in this manufacture.

THE moſt common materials out of which nitre is made, and, therefore, called the *matrix* of nitre, are the rubbiſh and earth of old houſes, and eſpecially of dove-cotes, ſtables, and church-iſles; particular fat earths; the aſhes of burnt vegetables; putrefied animal or vegetable ſubſtances; and ſome particular kinds of ſtones. Theſe materials are expoſed to the air for ſome months, particularly the winter months; for, during that time, nitre is generated in the greateſt plenty. The place where the materials are expoſed, ſhould be acceſſible to the air and winds, but not to the rays of the ſun, or to the rains. The air is neceſſary, as it generates the nitre; but the ſun is deſtructive, as it exhales it. The rains are prejudicial, becauſe they waſh it away when made. Drought is as deſtructive, as that exhales the ſaline parts after they are formed, and hinders the fermentation, neceſſary to draw the nitre, and to open the matrix to receive it. It is obſerved, that the north winds are particularly productive of of the ſalt. In the *Indies*, from which we have moſt of our nitre, they expoſe earth of a particular kind, mixed with putrefied vegetables, to the air, and from that extract the nitre. *Tournefort* tells us, in his travels, vol. 2. p. 289. "In our converſation in "the caravanſera of *Erzeron*, we learned "from thoſe of the caravan of *Wan*, a "*Turkiſh* town on the frontiers of *Perſia*, "that they carefully lay up in heaps the "dirt of the great roads, which are fre-"quented by caravans of camels. This "earth they waſh, and every year get out "of it about 100 quintals of nitre."

In the manufactory of nitre at *Paris*, where there is much made, they expoſe the rubbiſh of old houſes, mixed with the aſhes of burnt vegetables, to the influence of the air for ſome months, and moiſten it often with ſtale urine; and from thoſe materials extract their nitre. After all the nitre is got out of them, they are as fit as before to form more; and are again thrown on the heap. This fact ſhows, that this ſalt is not the natural ſalt of the earth, but formed by its expoſition to the air. After theſe earths have been expoſed a ſufficient time to the air, they are put into different caſks, and water poured over them, to lixiviate or diſſolve the ſalts. The materials muſt be frequently ſtirred about in the water, that it may diſſolve the ſalts. After the water is ſufficiently impregnated with the ſalts, they draw it off, and add to it ſome quick-lime, and the aſhes of vegetables or alkaline ſalts, if it has not already got enough of them; the former to ſeparate the oil from the ſalt, the latter to give it a fixed alkaline baſe inſtead of an earthy one. They add alkaline ſalts, as long as their addition makes the liquor take a milky appearance, and yield a precipitation. When no more precipitation happens, then they decant the liquor, and boil it up.

LET us now inquire into the origin of nitre. There are various opinions about this

this ſalt; nor are chymiſts yet agreed about its birth. Some alledge it is attracted, as we ſee it, from the air; others, that it is produced from the animals and vegetables, or their juices mixed with the nitrous earth, and putrefying there: others, that it is formed from the vitriolic acid, joining to the phlogiſton, or inflammable matter of theſe ſubſtances: and others, that the acid of nitre is a different acid from the former, and attracted by theſe bodies, which are its proper matrix. Let us examine theſe different opinions.

SALTPETRE is an artificial body, as none of it has ever yet been found in the bowels of the earth. Some authors, on this account, thought that the nitre was altogether attracted from the air by the materials expoſed to it. But this opinion is apparently falſe, as no nitre can be got from thoſe materials before an alkaline ſalt is added to them. The acid, indeed, does exiſt in theſe materials, as I ſhall afterwards

wards ſhew; but the alkaline baſe muſt be given it by art, before any nitre will cryſtalliſe. Beſides, nitre is not of itſelf a volatile body; and, therefore, cannot float in the air. The aereal nitre, which is got ſticking to old walls, is a very different ſubſtance from the nitre we are juſt now treating of. It has very different properties, ſuch as effervεſcing with all acids, and a urinous taſte.

LEMERY, in a paper in the *Mem. de l'acad. des ſciences pour l'année* 1717, maintains an opinion peculiar, I believe, to himſelf, That the nitre which is generated, ariſes from the animal and vegetable ſubſtances which are uſed to collect it. The arguments which he makes uſe of to ſupport his opinion, are, indeed, few and weak. I think his chief one is, that he has extracted a nitrous ſalt from ſome vegetables. It is true, that ſome of them do contain, in their natural ſtate, an inflammable ſalt, which appears to have many of the

the properties of nitre. This is the caſe with the carduus benedictus, wild cucumber, and pellitory. *Boildue*, in 1734, has a paper in the academy of ſciences, where he ſays, that he extracted real nitre from a decoction of bourache, eſpecially when he added ſome quick-lime to it, to fix the oily particles the better, that the ſalts might cryſtalliſe. He ſays, that a mould which formed itſelf on this decoction, after it had been kept for ſome time, burnt like oil and nitre. But all this is no proof, that the nitre comes from the vegetables uſed in the making nitre; for all kind of vegetables do equally well, even thoſe which contain a vitriolic ſalt. Beſides no fixed ſalt is ever got from putrefied vegetables, or from any animal ſubſtance, which *Lemery* ſeems to have forgot. It is ſurpriſing, that a chymiſt ſhould fall into ſo great an error. Theſe vegetables and animal ſubſtances act, as we ſhall ſoon ſee, in a very different way, by affording an abſorbent earth, and volatile alkaline ſalt, and ſo increaſing the

matrix

matrix to extract the acid from the air; and by keeping the matrix open to admit the air, by a continual fermentation carried on in the body expoſed.

THE third opinion, which almoſt all chymiſts follow, is, That the alkaline volatile ſalts, produced by the fermentation of corrupted bodies, animal or vegetable, and the abſorbent terreſtrial particles, which are uſed as the matrix to make nitre, attract from the air, which is plentifully ſtored with it, the *acidum vagum*, or vitriolic acid; which joining with the oil of the matrix, ſtored with it, becomes the acid of nitre. This univerſal acid, *Homberg* makes the origin of the nitrous and the marine acid: for, added to an inflammable matter, it becomes the nitrous acid; to an arſenical matter, it becomes the marine acid. The arguments uſed in favour of this opinion are, 1. That putrefied animal ſubſtances are employed in the formation of nitre, and, therefore, the oil

muſt

muſt join with the vitriolic acid. But this concluſion will not be allowed as a juſt one, ſeeing theſe putrefied ſubſtances may have other uſes, as we will ſhow. It will preſently appear, that nitre may be got without any oily matter. 2. The ſpirit of nitre has a reddiſh colour, which they ſay is an argument, that it contains an inflammable ſubſtance, and it is that ſubſtance which gives the colour to all bodies. But we know many bodies which are coloured, although we have never yet been able to ſhew that they contained an oil; therefore this may not. 3. The inflammability of nitre, which it owes to its acid, proves, they ſay, that it contains an oily principle, which is the only inflammable body that we know. To this opinion the anſwer is plain, That nitre of itſelf is not inflammable, unleſs it meets with an inflammable body. This argument becomes rather an objection againſt this opinion, as it may be ſaid, that nitre inflames with all bodies which contain an oil; and as it is

not

not inflammable of itſelf, therefore it does not contain an inflammable ſubſtance.

THIS leads me to the laſt opinion, That the nitrous acid exiſts in the air, and is attracted from it. This opinion, though ſcarcely maintained by any chymiſt, to me appears to be the ſtrongeſt, though ſtill liable to ſome objections. The firſt argument for it is, That alkaline ſalt and calcarious bodies of themſelves, without a mixture of any vegetable or animal matter, will produce nitre; as we find by an experiment of *Stahl*, in which he got nitre by expoſing alkaline ſalts to the air. I have got a nitrous ſalt from the lime taken out of park-walls. The ſecond is, That it is actually found exiſting in nature. Many mineral waters contain a nitrous ſalt, as appears by the experiments of *Du Clos*, performed before the academy of ſciences at *Paris*. I have diſcovered that the nitrous acid exiſts in all hard waters*; and that

* *Vid.* Experiments on bleaching.

all

all pit-well waters are hard, and contain a nitrous acid joined to an abſorbent baſe; which imperfect ſalt, by the addition of an alkaline ſalt alone, can be converted into real nitre. Thirdly, by boiling hard water, or expoſing it to a great degree of heat, the nitrous acid is really volatiliſed, and the abſorbent earth falls to the bottom. This proves, that the nitrous acid is volatile, and exiſts in the air. The *ſpiritus nitri fumans* is continually evaporating in the air. Theſe experiments prove, I think, beyond all doubt, that the nitrous acid exiſts in the air, diſtinct from the vitriolic acid. This nitrous acid appears to be the fructifying principle which we formely diſcovered in the air.

THIS point being ſettled, let us now account for the different changes brought about in the making of nitre. All earths are not fit for this purpoſe; only ſuch as are attracters of acids, or abſorbent earths, *viz.* lime, marl, and the other abſorbents; or or putrefied vegetables and animals, which afford an abſorbent earth, and likewiſe a volatile ſalt. Almoſt all earths have more or leſs of abſorbent particles in their compoſition. Theſe abſorbent earths catch the nitrous acid, as it paſſes by them with the air, or fix and collect it as it ariſes from the inner parts of the earth: for I am not ſure but it may be got likewiſe in that way; at leaſt it does not ſeem to riſe very high from the ground. *Mariot's* experiment is a proof of this. He expoſed the matrix of nitre for two years on a houſe-top, and could get no nitre from it; but got it from the ſame matrix kept in a cellar.

The mixture of urine, and of putrefying vegetable and animal ſubſtances, will be of conſiderable uſe in carrying on an inteſtine motion in the maſs of earth, keeping it open, and allowing the influence of the air to penetrate deeper into the body. If there was no ſuch putreſcent body mix-

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ed with it, the maſs would cohere too firmly together, and its ſurface would only act; whereas now the whole body acts. It is in this way that I imagine the animal and vegetable ſubſtances chiefly operate, and not by entering into the compoſition of the nitre, as moſt chymiſts aſſert; becauſe nitre may be made by expoſing alkaline ſalts alone to the air; for alkaline ſalts attract acids, and are ſo looſe as to ſtand in need of no fermentation to open their texture. The north wind is particularly proper for the generation of nitre, becauſe that wind muſt bring more of the nitrous acid along with it. That the cold we feel from that wind, is chiefly owing to a greater quantity of this acid, I think is probable, though not demonſtrable. The winter months are particularly good, as the north wind blows more in that ſeaſon than in any other, and as there is leſs heat to exhale the nitre during the operation.

In this way the matrix of nitre is impregnated with the acid of nitre. Let us now ſee what this matrix at preſent contains. We have the analyſis of it by *Petit* in the academy of ſciences. He took 50 l. of old plaiſter, and diſſolved it in 72 lb. of water. This gave a pungent bitter reddiſh liquor, which was in weight to common water as 32 to 31. When the water was boiled into a liquid extract, for it would not harden, it ſoon attracted the moiſture, and turned liquid again. It turned blue paper red; ſhewed no effervеſcence with *ſp. nitr.* or *ſp. ſal. mar.*; and when mixed with the former, diſſolved leaf gold. *Ol. vitr.* made a violent fermentation and precipitation with it. *Ol. tart. p. d.* did not eaſily mix with it; but when ſtirred, produced a *coagulum* like butter, and gave a ſtrong urinous ſmell. If ſublimate was mixed with the *ol. tart.* no urinous ſmell was felt. This *coagulum* was owing to a ſeparation and precipita-

tion

tion of much earth. Spirit of urine had the ſame effects; but *ſp. ſal. ammon.* made with lime, had not. Brown paper dipt in it, burned like a match. Theſe experiments ſhow, that it contains abſorbent earth, volatile ſalt, the acid of nitre, and ſea-ſalt.

He diſtilled it for five days, and nothing but phlegm, very much charged with a bitumen, came over. When the utmoſt force of fire was applied, white clouds appeared in the receiver, which clouds condenſed into *aq. reg.* By two other diſtillations he got *ſp. nitr.* When *ol. vitr.* was added to it, there happened a violent ebullition, and *aq. reg.* was diſtilled from it. By the aſſiſtance of quick-lime a ſmall quantity of *ſp. vol. urinæ* was got. It appears again to contain an oily ſubſtance, earthy matter, volatile ſalt in a ſmall quantity, ſome of the marine acid, and a great deal of *ſp. nitr.* It is eaſy to account from whence it has got the inflammable matter and volatile ſalt, *viz.* from the putrefied vegetable and animal ſubſtance mixed with it. The ſea-ſalt comes from the urine of animals poured on the matrix of nitre. But he never could extract real nitre from this nitrous earth. That cannot be done, till it has got the addition of an alkaline ſalt by itſelf, or contained in the aſhes of vegetables. Theſe are generally added to the nitrous maſs before the water is poured on; if not, they muſt be added afterwards.

THE effect which they produce is, to join with the nitrous acid, whenever a ſufficient quantity of water is added for them to act: for alkaline ſalts attract the acid of nitre more ſtrongly than the earthy baſe does, and the earth is ſhaked off. Hence it happens, that in boiling, the liquor depoſites much of this earth. There ſhould as much alkaline ſalt be added, as to ſaturate the nitrous acid fully, and ſhake off all the abſorbent earth. The alkaline ſalt

cannot

cannot join to the marine acid, becauſe that has already got an alkaline baſe.

If theſe abſorbent earths attract the acid of nitre from the air, in the manufacture of nitre, ſurely they will do the ſame when laid on the earth, and be converted to the ſame ſalt, conſiſting of the nitrous acid and an abſorbent baſe. It is not, therefore, a real nitre, as was thought, which is the cauſe of vegetation, but an imperfect nitrous ſalt. This reaſoning admits yet of ſtronger proof, when we conſider, that this very ſalt exiſting in hard waters, has already, by experiment, appeared to be a great aſſiſtant of vegetation; and that an artificial one, of much the ſame nature, compoſed of lime and ſpirit of nitre, when joined with a proper quantity of an oily ſubſtance, rendered a poor ſoil remarkably fertile.

If this reaſoning is juſt, the effects of different manures on the ground ſhould be visible, in proportion to their strength of attracting acids. This happens really so in fact, and is a strong confirmation of the truth of our reasoning: for ashes have the speediest effects of any manure; because the alkaline salts which they contain attract acids stronger than any body. Soot and dung come next, which are volatile alkalines, whose attraction comes next to the first; then the class of absorbent earths. The same observation is made of the marls; for, according to their rank as attracters of acids, so they operate on ground; first shell, next clay, and last of all stone marl; which will sometimes continue in the ground four or five years before it show any effects. The same turn all these manures keep in losing their effects; for the soonest converted to salt must be the soonest exhausted.

An objection will naturally occur to every one against this opinion, though supported by the greatest strength of experiment: which

which is, That no ſuch nitrous ſalt is got from fertile earth. In general, theſe abſorbent particles are in ſuch ſmall proportion, even in the richeſt ſoil, and ſuch a ſmall degree of fermentation is carried on in it, that there are only a few of theſe particles, and theſe too on the ſurface, capable of being converted to this ſalt; and they are no ſooner converted than abſorbed by ſome plant. Theſe conſiderations ſhew, that little of this nitrous ſalt is to be expected from any ſoil. That it is ſometimes got, appears from this paſſage of Lord *Bacon*, *Hiſt. vit. et mort. Certiſſimum eſt, quamcunque terram licet puram, neque nitroſis admixtam, ita accumulatam et tectam, ut immunis ſit a radiis ſolis, neque emittat aliquod vegetabile, colligere etiam ſatis copioſe nitrum.*

Almost every perſon who has examined the contents of this ſoil, has denied, however, the exiſtence of this nitrous ſalt in it. Let us apply to experiment for a deciſion of this queſtion.

Exp. 37. To put this queſtion beyond all doubt, I took from a molehill ſome rich ſoil in the month of *October*, poured water on it, and filtered that water through brown paper. This liquor, when boiled up, was yellow, and taſted ſaline. The ſalt appeared plainly to be nitrous; as brown paper, dipt in this liquor, and dried, burnt like a match. On an addition of *ol. tart. p. d.* the liquor turned milky, and let fall a white powder; which ſhows the ſalt to be of the ſame nature with that of hard water. At firſt, I could get no ſalt by cryſtalliſation, as the liquor was very unctuous, and in ſmall quantity. But on treating it in the ſame manner as the manufacturers do the materials of nitre, *viz.* adding ſome quicklime to ſeparate the oil from the ſalts, and allowing it to ſtand ſome days, I got from it a true ſaltpetre. This experiment ſhows the ſaline part of the vegetable food to the eye.

FROM

From what has been ſaid we may learn,

Cor. 1. That as hot weather hurts the formation of nitre, by exhaling it, and as the winter and ſpring is the time in which it is moſtly generated, all dung ſhould be laid out in thoſe ſeaſons.

Cor. 2. As theſe manures become fertile by the action of the air, the longer they are expoſed on the ſurface of the earth, ſo much the faſter will they be converted to the nitrous ſalt. Farmers are now convinced of this from experience: but ſuch bodies as contain a nutritive juice already formed, as woollen rags, hair, horn-ſhavings, leather, ſaw-duſt; or thoſe which already exiſt in the form of a neutral ſalt, ſuch as ſea-ſalt, cannot be benefited by the influence of the air. Experience has likewiſe confirmed this obſervation. Theſe are ſtrong proofs of the juſtneſs of the preceding reaſoning.

Cor.

Cor. 3. As the north wind is obſerved to bring moſt of the nitrous acid, it would ſeem to follow, that banks which have a north aſpect ſhould receive moſt of it. It is obſerved, that they are, in general, richer than thoſe of a ſouthern aſpect. As the former have not ſo much ſun as the latter, they ſhould be leſs fruitful: but our theory of vegetation affords a ſufficient reaſon for this fact.

Cor. 4. It appears, from the manufacture of nitre, that all thoſe abſorbent meagre earths uſed in agriculture, will be rendered more capable of anſwering their purpoſe, by an addition of ſome putrid ſubſtance, vegetable or animal, to open their texture, and make them more pervious to the influence of the air. Hence the advantage of mixing animal or putrefied vegetable ſubſtances with chalk, marl, lime, or the aſhes of vegetables.

Cor.

Cor. 5. As the proceſs for preparing vegetable food is the ſame with that for making nitre, farmers ſhould imitate the manufacturers of nitre, and the nearer they approach to the methods found moſt convenient to increaſe the product of nitre, the more will they multiply the vegetable aliment. In *France* all old walls and houſes belong to the King, and are made uſe of for the extraction of ſaltpetre. The King of *Pruſſia*, by a regulation of conſummate policy, has eaſed his ſubjects of this burthen, ſhortened the proceſs, and increaſed the quantity of ſaltpetre. He has ordered walls of certain dimenſions to be built near every village; they are compoſed of the earth of granaries, ſtables, or cellars, mixed with other fat earth. They are built to ſtand ſome years, till they are ſufficiently impregnated with ſaltpetre. It is obſerved by Dr. *Pietſch* in his *Penſes ſur le generation de nitre*, that the people employed in theſe works, are yet very ignorant,

that

that they might meet with much fat earth below the ſurface, very fit for their purpoſe, and that there ſhould always be a proportion of abſorbent or calcarious earth in theſe walls. He ſays, that there is always leaſt nitre on the ſouth ſide of the wall. He orders, that all vegetables ſhould be pulled from the walls, as they conſume the nitre; that no cattle ſhould be allowed to come near them, as they are fond of it; and that they ſhould be covered with ſtraw, to hinder the rains from waſhing off the nitre: what ought then to hinder our farmers from making ſuch walls of fat earth, dung, eſpecially that of pigeons, ſtraw, which will take a time before it rots, and a ſmall proportion of lime, marl, or ſhells? Moſt of theſe materials will be found every where. In two years they would become a very rich manure. They would operate inſtantly; whereas, it takes two years before many of our manures have a ſenſible effect on the ſoil. Although heavy rains waſh off the nitre, yet a gentle

moiſture

moiſture of the materials is of uſe, as it is neceſſary to the attraction of all ſalts. It has been obſerved, that the ſouthern ſide of theſe walls has leſs nitre. To remedy theſe defects, I would propoſe, that the wall ſhould be ſhadowed on the ſouth by a hedge, which will keep off the rays of the ſun, hinder it from turning too dry, and allow the air a free paſſage. The putrefaction, which goes on in ſuch a ſituation, will be of great advantage to the proceſs.

PART

PART IV.

SECT. I.

Of opening and pulverifing the foil.

IT is not only the bufinefs of the farmer to provide food for plants, but to take care that they are able to reach that food. It is of no ufe if the roots cannot pierce the ground, to get at it. Hence the neceffity of opening or pulverifing the foil. Plants are fed moftly by their roots; nor do they begin to grow, until thefe roots are fo numerous as to nourifh both themfelves and the ftem. The wider thefe roots are fpread, the more nourifhment will the plant receive, the ftronger will it be, the larger will it grow, and the better will it anfwer the defign of nature.

BUT this is not the only view with which we fhould favour the growth of the

root,

root. That part ſeems to be the great cauſe of fecundity; for it not only nouriſhes the plant, but ſends up many ſhoots and plants itſelf. A ſmall piece of the root of many different plants will breed a plant. Many ſtalks ariſe from the roots of all the different grains, long after the grain itſelf is corrupted. Hence, the more roots the more chance of plants: but the quantity of roots ſeems to depend, in a great meaſure, on the openneſs of the ſoil.

The ſoil may indeed be too looſe; for it muſt have a certain conſiſtency and cohesion to ſupport plants. The gravelly ſoil is the worſe of being often ploughed. It is obſerved, that a light ſoil, when much dunged, produces a worſe crop of peaſe than when not dunged. But too great looſeneſs is a rare fault, and is ſooner remedied. Too great ſtiffneſs of the ſoil is what the farmer has moſt frequently to ſtruggle with.

Let us, then, examine the methods by which it is kept looſe. Theſe may be divided into natural and artificial.

SECT. II.

Effects of the atmoſphere.

THE alternate viciſſitudes of the air, are the chief means that nature makes uſe of to attain this end. Heat and cold, moiſture and drought, contract and dilate it by turns; and, by theſe alternate motions, ſhake the particles aſunder. But there are no means ſo efficacious as froſt and thaw. Every one muſt have obſerved, how looſe the ſoil is after a froſt. Many vegetables are at this time ejected out of the earth altogether.

Frost ſeems to act in different ways. 1ſt, By changing into an elaſtic ſtate much of the fixed air, which muſt ſhake and open the ground, to gain an exit. 2dly, By

By the dilatation of the water, as it freezes in the earth, the adhering particles muſt be ſeparated. 3dly, The particles of water ſhooting out in the manner of ſalts, muſt cut and divide the ſoil.

Cor. That the ground may receive, in the ſtrongeſt manner, the good effects of froſt, it would appear reaſonable, that it ſhould get one ploughing before the froſt comes on. One furrow at this time will attenuate it more than two afterwards. Regard muſt always be had to the climate; for where much rain falls in the winter, this practice would prove pernicious, by expoſing the ſoil to be waſhed away.

S E C T. III.

Change of ſpecies.

THERE are ſome plants deſigned by the author of nature to fix the ſoil; there are others deſigned to open it. One great diviſion of plants is into the fibrous and carrot rooted. The fibrous-rooted divide directly into ſmall fibres, which run in all directions, but moſtly horizontally; the carrot-rooted ſend one great ſtem directly down, which has lateral fibres. The former, in which claſs are reckoned all the white grains, rye-graſs, *&c.* conſolidate the ground; while the latter, in which claſs are reckoned the liguminous plants, carrots, turnips, clover, *&c.* attenuate and looſen the ſoil exceedingly. The clover is often ejected altogether out of the ground after a froſt.

This effect muſt depend on the nature of the roots. The fibrous roots muſt bind the ſoil together like ſo many threads, while the carrot root deſcends like a wedge, and by its mere mechanical force cuts the earth; perhaps the latter may operate, likewiſe, by ſeparating more moiſture from its root to keep the earth looſe. Some plants appear to have this quality. A

ſprig

ſprig of mint, which has ſome roots in water, and ſome in earth, will, according to *Tull's* experiment, moiſten the earth from its roots. The liguminous plants, by covering the ſoil, keep it moiſt, hinder the ſun to conſolidate it, and deſtroy the weeds which help ſo much to bind it. Hence the reaſon why a change of ſpecies meliorates the ſoil ſo much. When the ground is often ſowed with white grain, it turns ſtiff. A crop of peaſe, beans, or clover, pulverizes it again.

Farmers have diſcovered, by experience, that all the fibrous-rooted plants impoveriſh the ground, and do not thrive when they ſucceed one another; while the carrot-rooted enrich the ſoil, and may follow one another with ſucceſs. The latter, by opening the ground, make the influence of the air on it reach deeper, and conſequently help to produce more of the vegetable food; while the former, by conſolidating the ground, ſhut out in a great meaſure, the influence of the air, and make the ground leſs fertile.

It is remarked, that not only a change of ſpecies, but alſo a change of grain, is neceſſary: for the ſame grain ſown in the ſame ground is obſerved to degenerate. This depends on another cauſe. It ſeldom happens, I believe, that the vegetable food is of a due mixture and conſiſtency. As ſoils are generally either too wet or too dry, too light or too ſtiff; ſo muſt the vegetable food be either too thin and watry, or too thick and gluy. The vegetable muſt at laſt be hurt from a conſtant ſucceſſion of one ſort of food, and can only be recovered by a ſoil poſſeſſed of oppoſite qualities.

SECT. IV.

Of ploughing.

PLOUGHING is the artificial method of pulverizing moſt known and moſt practiſed. It acts in two ways; by an immediate mechanical diviſion and trituration of the ſoil, and by a more frequent and extenſive expoſition of it to the influence and viciſſitudes of the atmoſphere. I believe the latter operation is the principal one; for ſo groſs an inſtrument would ſeem very unfit to prepare the earth to enter the capillary veſſels of plants. Its effects, however, are very remarkable. They are beautifully and ſtrongly illuſtrated by the ſtory related by *Pliny* of *Caius Furius Creſinus*. That farmer, having better crops than his neighbours, fell under the ſuſpicion of witchcraft, was accuſed before the people, and ſaw himſelf ready to be condemned to death. When the tribes were going to vote, he at once produced his ruſtic inſtruments, of a greater ſize than common, larger oxen, and heavier ploughs; and added theſe remarkable words: *Veneficia mea, Quærites, hæc ſunt; nec poſſum vobis oſtendere, aut in forum adducere, lucubrationes meas, vigilias, et ſudores.* He was unanimouſly abſolved.

The good effects of ploughing depend entirely on the drineſs of the ground: for if it is wet, the ground is conſolidated inſtead of being opened; and remains in that uſeleſs ſtate till the next winter's froſt looſens it again. None but dry bodies can be reduced to a powder.

The farmer muſt open the ground as deep as the roots of his corn penetrate, that they may find an eaſy paſſage: and yet he muſt take care not to go below the ſoil in ploughing, elſe he will bury what has been benefited by the air, and expoſe to the air what perhaps cannot. Hence the plough muſt

must be proportioned to the depth of good soil.

It seems strange, that there is not a more certain way of fixing the depth of the plough, and preserving it in that precise situation which the soil requires, than the attention of the ploughman. That must be often suspended by external objects and fatigue; and then the cattle and soil suffer. Does not the wheel-plough remove this objection?

The stiffer the soil, the oftner should it be ploughed. Clay cannot be ploughed too often; lighter soils perhaps may. It is allowed by many farmers, that the gravelly soil may be hurt by too frequent ploughing.

As this operation depends on the principles of mechanics, and not on those of chymistry, I shall leave it almost untouched to the consideration of some other person. It is a subject worthy of attention; and al-

 though

though well enough underſtood, perhaps, for common practice, yet has it not been reduced to that mathematical exactneſs which all mechanical agents are capable of. I wiſh that ſome practical farmer, ſkilled in mechanics, would lay down the principles on which ploughs ought to be conſtructed, and ploughing conducted. He would merit much from the community.

SECT. V.

Of composts.

THERE is another method which art uſes to keep the ſoil looſe; and that is, by the admixture of putrid and fermenting bodies. We have ſeen that theſe bodies have a ſtrong inteſtine motion before they are laid on the ground: they continue that afterwards, though in a ſmaller degree. The fat ſoil of church-yards ſwells ſo much when expoſed to the air, by its fermentative power, that it will not go altogether into the ſame hole out of which it was dug. Clay, which has ſo few putreſcent particles, is the moſt adheſive ſoil of any. We have ſeen already how much ſhells, when they begin to putrefy, open the ſoil.

BUT there are other compoſts, though not of the putrefiable ſort, which have this attenuating power in a ſtrong degree. In this claſs are all the marls, but eſpecially the ſofteſt, ſuch as the clay marl. We have found how readily they loſe all adheſion in water, and fall down into a powder. The ſame power they communicate to other earth, even to the moſt adheſive. The following experiment is a proof of this.

Exp. 38. Take equal parts of marl and clay, mix them well together, and dry them; when this compounded ſubſtance is put into water, it falls by degrees to the bottom of the glaſs in the ſhape of a powder, while a ball of pure clay remains quite

quite undiſſolved in water. This ſhows the ſtrong attenuating power which marl has, and which no other body can come up to. It is obſerved, that all clay grounds, after they are marled, dry fourteen days ſooner than what they did before. This is owing to the ſoil being more looſe, by which means the water pervades it more eaſily.

I KNOW that this opinion contradicts the common one, that marl is not fit for clay grounds. From whence the latter has taken its riſe, I know not, if it is not that bodies of ſuch a ſimilar appearance cannot be allowed to benefit one another. But the experience of many counties where marl is uſed, and where the ſoil is generally a deep clay, contradicts this vulgar opinion. The following experiment puts it beyond all doubt.

Exp. 39. I filled a pot with clay of the ſame kind I had uſed in the former experiments,

ments, which had been expoſed to the air for four months, and ſeemed to have no mixture of any other earth with it, as it made good brick, with the addition of ſand; and had been taken up ſeven or eight feet below the ſurface. This pot I ſhall call N° 1. Pot N° 2. was filled with equal parts of clay and marl; N° 3. with equal parts of clay and ſoured lime; N° 4. with equal parts of clay and ſea-ſand well waſhed; N° 5. with equal parts of clay and dung. Theſe different compoſitions were turned daily. On the 26th of *April* ſix grains of barley were ſown in each.

May 14. N° 2. had two plants, above ground; N° 3. had four.

May 17. N° 2. had ſix; N° 3. had ſeven, two of which were from one grain; N° 4. and 5. had one each.

May 21. N° 1. had five, of which two were an inch and a half high; N° 2. had

ſix

ſix two inches high; N° 3. were about the ſame height; N° 4. had two, one of which was one inch high; N° 5. had three, each two inches high.

June 4. N° 2. talleſt and greeneſt; N° 3. very near it; N° 1. and 5. of an equal height, but the latter of a very light colour; N° 4. worſt of all.

Aug. 20. N° 1. about nine inches tall, and much withered. The roots ſeem not to have pierced the clay, but to have ſunk along the cracks. N° 2. has nine ears, and thoſe of a very deep green colour. N° 3. has eight, but not of ſo deep a green. N° 4. has five, and thoſe much ſmaller. N° 5. has nine, almoſt as good as N° 2. I had no opportunity of ſeeing them afterwards.

Cor. 1. By this experiment it appears, of what great advantage it is to manure clay; for, of itſelf, pure clay is not capable of pro-

producing good plants, becauſe their roots are not able to penetrate it.

Cor. 2. Sand appears, in oppoſition to the common opinion, to be the worſt manure of thoſe uſed. It cannot indeed ſeparate the minute particles of the clay, which is the only uſeful ſeparation for the growth of vegetables. A little ſand rather ſeems to increaſe the union of the particles of clay, as appears from the manufacture of brick. see a Treatise of Agriculture Edinb. 1762 p. 418

Cor. 3. Lime ſeems to be a good manure for clay. What I uſed had been ſoured for ſome time. The effect which the air has on it, in changing it from quick-lime to effete lime, muſt open the ground conſiderably.

Cor. 4. Dung and marl appear to be the beſt manures for clay. The former has a ſtrong fermentation; the latter loſes all coheſion when water is added.

SECT.

SECT. VI.

Of vegetation.

IT is worth our pains to take a ſhort view of what muſt happen to the vegetable food in the veſſels of plants. To enter into a diſcuſſion of the anatomy of plants, would be foreign to the ſubject. I ſhall take that as demonſtrated by botaniſts.

THE nitrous ſalt being formed on the ſurface of the ſoil, will be waſhed down by the dews and rains. It will diſſolve what oils it meets with in its way, and conſtitute with them a ſaponaceous juice, containing, beſides the former principles, fixed air and fixed fire. This juice will be retained in the ſoil; becauſe I ſhowed by experiment, that fertile ſoil acted like a ſpunge with reſpect to water. This natural deſcent from gravity, and the natural aſcent from the heat of the earth and in-

fluence

fluence of the ſun, muſt keep the nutritious juice in a continual motion; ſo that it muſt be continually applied to the roots of plants deſtined for the admiſſion of nouriſhment.

THE firſt queſtion which can raiſe any doubt here is, In what manner do the juices ariſe to the tops of plants and trees? *Malpighius* thinks, this is owing, in a great meaſure, to the air-bladders which he diſcovered in the ſtructure of plants, and which he thought behoved to dilate and contract, according to the different changes of heat and cold which happen in our atmoſphere. To me it does not appear, that the dilatation of ſuch veſſels would force it more upwards than downwards. I ſhould rather imagine, that ſuch a dilatation would ſtop the motion altogether.

THE cauſe commonly aſcribed, *viz.* the action of capillary veſſels, appears to me ſufficient for that end. *Hales* has demon-

ſtrated

ſtrated the fact to the eye, by ſeveral experiments, in which a part of a branch, being cut at both ends, and having its under part immerſed in water, a moiſture was immediately perceived in its upper part. This effect of capillary tubes muſt ariſe from the attraction betwixt the ſubſtance of which they are compoſed and water.

THE attraction betwixt wood and water appears to be very ſtrong, by an experiment related by Dr. *Taylor*, in the *Philoſophical Tranſactions*, N° 368. He hung at a pair of ſcales a piece of fir board, ſoaked it in water, weighed it, and then immerſed it again in water. To raiſe this piece of wood, which had a ſurface of an inch ſquare in contact with the water, fifty grains over and above its former weight were required. The additional weight in the different trials, he ſays, was always proportional to the ſurface. The diſtance of the under ſurface of the board from the ſurface of the ſtagnating water,

at

at the time of ſeparation, meaſured upwards of $\frac{16}{100}$ of an inch. This additional weight is the real meaſure of the attraction betwixt that ſurface of wood and water in contact.

There is another force that muſt contribute to raiſe the ſap, *viz.* the natural attraction betwixt the conſtituent parts of the fluid. This muſt certainly be the caſe, when the ſap moves quickly, as in the vine in the bleeding ſeaſon. Both theſe cauſes acting, and the evaporation going on continually from the ſuperior parts of the veſſels, the ſap riſes from the roots of the plants to the extremity of their branches.

But nature does not intend that this ſhall be done too quickly. There are many ſpiral veſſels, and many cells into which the ſap is depoſited, and by which it muſt be retarded. In theſe the ſap will be much altered in its nature, by the motion of the plants, by the continual motions of the air-veſſels, and perhaps by the particles of light taken in at the leaves. The juices are rendered richer by the expulſion of the watery particles. The remaining ones are partly applied to the extremities of the veſſels, which run in all directions, horizontally as well as perpendicularly, and make the plant increaſe in breadth and length; and partly go to the formation of leaves, flowers, fruit, *&c.*

It is eaſily conceived how plants, by the different combinations of the five principles of which their food is compoſed, and the combination of theſe in different degrees, muſt differ very much in their juices and products. If their groſſer particles are to be ſeparated for any uſe, the ſubtiler are all carried off by lateral veſſels, until none are left but what are wanted; if the ſubtiler particles are to be uſed, they are to be ſeparated by ſmall veſſels fitted to receive them, implanted in the larger, or in the cells where the juices are depo-

poſited

fited. In this way particles of any fize may be lodged in any part of the plant. Hence all that variety in the falts, oils, and figures of plants. Hence all that variety of fmells, taftes, virtues, and other qualities.

How ftrong the power inherent in the veffels of plants to change and alter thofe fubftances which are taken in, appears from an experiment of *Homberg*. He filled two pots of earth mixed with fome falt-petre. Into one he put creffes, which is an alkalefcent plant, and affords a volatile alkaline falt, but no acid; into the other fennel, which is an acefcent plant, and affords an acid on diftillation, and no alkaline volatile falt. He filled two other pots with earth, which had all its falts wafhed out, if there were any in it. Into one he planted fennel, and into the other creffes, as in the former. The two plants in the nitred pots 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 in the earth. This experiment ſhows, 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.

But how ſhall we account for the different external forms of plants? Shall we fly to the immediate hand of the Supreme Being? or, as this ought to be the laſt ſtep in philoſophy, can we find no chymical agents capable of this effect? From many experiments, which ſhow the natural inherent power in ſalts, eſpecially the nitrous kind, to run into vegetations, as they are called, and to take the figure of plants, with branches, leaves, nay even an appearance

of

of fruit, owing to the ſtrong attachment ſubſiſting between them and water, I have often been led to think, that the vegetative power of plants, nay their particular forms of vegetation, were owing to that vegetative power inherent in their ſalts. In effect, we ſee that vegetative power ſtrongeſt when moſt ſalt enters their veſſels; that is to ſay, in the ſpring.

Thus I have endeavoured to account for the effects of manures on the different ſoils, and for the riſe and changes of the vegetable food in the veſſels of plants, from thoſe remarkable attractions and affinities which the Author of all has endued the ſmaller particles of matter with. Theſe are not, as is commonly imagined, mere paſſive bodies; but active, vigorous, and capable of producing thoſe changes by which nature is ſupported. I have demonſtrated theſe affinities by experiment; I have aſſumed no other principles; I have built my whole plan on theſe; I hope, therefore, that its ſimplicity will be a ſtrong proof of its truth.

BUT whence theſe elective attractions which move the whole? Whence acquires matter the power of acting without itſelf? for that muſt be the caſe, unleſs we ſuppoſe an endleſs chain of material agents. Whence but from an immaterial being, who, by his order, firſt fixed theſe properties to matter, and, by his immediate will, conſtantly ſupports them in the ſame tenor? It is on particles too minute for human eyes, that the omnipotent hand chuſes to exert itſelf, and on their powers to erect this beauteous ſyſtem. Hence the origin of all motion, adheſion, increaſe, and organiſed matter.

BUT as all individual forms were deſigned to be of finite duration, he eſtabliſhed other particles with repulſive powers, and mixed the ſeeds of diſſolution with the firſt rudiments of organical life. While the

the veſſels are pervious, and the motion of the fluids ſubſiſts, the attractive overbalance the repulſive powers, and the vegetable or animal life continues. But when that motion ceaſes, and other circumſtances concur, the repulſive become too ſtrong for the attractive powers, diſſolve the compoſition, and reduce the body to thoſe particles of which it was at firſt made up. This is the great circle that Omniſcience has marked out, and Omnipotence circumſcribes itſelf to, for the greateſt good of the whole.

PART V.

SECT. I.

Of weeds.

THE laſt article which we propoſed to conſider was, what impediments there were to vegetation, and the methods of removing them. Theſe impediments are ſuch as either belong to the ſoil or to the plants. We ſhall treat of them according to this diviſion.

AMONGST the impediments of the ſoil, I claſs all ſuch vegetables, as, being of no uſe to the farmer, are called *weeds*, or *inutiles herbæ*. Theſe become hurtful to the growth of more valuable plants, by conſuming part of the nouriſhment. I here claſs alſo thoſe roots called *wreck* in this country, which run through the ground often in ſuch plenty, that they bind the

ſoil,

ſoil, hinder the roots of the corn to ſpread, and draw up a great deal of nouriſhment. Theſe are generally the roots of the quick graſs. The reſt-harrow has a large root, which goes very deep.

THESE weeds, and the roots belonging to them, are deſtroyed, 1. By ſummer fallowing. They are torn up by the plough when they begin to ſhoot, their roots are expoſed to the ſun, they ſoon wither, and are killed; or elſe they are buried below the ſurface.

2. A METHOD much analogous to the former, is trenching eighteen inches deep. This buries the plants ſo deep that they die; but this can only be put in practice where the ſoil is good to that depth.

3. ANOTHER method of killing uſeleſs plants is, to hoe them when young. That effectually roots them out.

4. No plants can grow without a ſufficient quantity of freſh air, which is as neceſſary to the vegetable life as to the animal. Whatever plants cover the ground cloſely, deſtroy all thoſe which grow below. Hence a good crop of peaſe kills all weeds by overſhadowing them; in ſo much that the farmer aſſures himſelf of a good crop of wheat if the peaſe are good. If they are not, a greater quantity of weeds comes up than uſual; and he never can expect any of the three following crops to be good, unleſs he gives the ground a fallowing.

It is in this way, likewiſe, that fog is deſtroyed. The incloſure is ſhut up from the middle of *May* to the beginning of *December*, and then fed from that time to *April*. After that it is ſaved for a crop of hay. The fog being ſo long covered by two ſucceeding crops of graſs, is cut off from the benefit of the air, and ſo dies.

5. There

5. THERE is yet another way of destroying these weeds; and that is, by marl. I have seen broom effectually killed by marl. I have seen a crop of wheat growing on a field which was partly marled and partly not. That part of the field on which marl had been laid, was free from all weeds, while the other unmarled part was full of them. The same wheat was sowed over the whole field. I can account for this effect of marl in no other way than this, that the grain is brought up so speedily as to be able to choke and destroy these weeds.

SECT. II.

Of a wet soil.

THERE is not a greater enemy to vegetation than the too great moisture of the soil. It is always owing either to a stratum of rock, or of clay, generally the latter, below the surface, which not allowing the rains to pass through, they can

can get off in no other way than by evaporation; a very ſlow method, when compared to filtration. Farmers expreſs the effects of water by ſaying, that it ſours the ground. It is not meant by this, that the ground becomes really acid, but only that it is changed in its nature, and rendered unfit for vegetation. The natural product of this ſoil are, ruſhes and ſour graſs; which laſt appears in the furrows, but ſeldom in the crown of the ridge; is dry and taſteleſs like a chip of wood; and feels rough, when ſtroked backwards. The natural effect of ſtagnating water I take to be, its putting an entire ſtop to the admiſſion, and conſequently to the influence of the air.

This exceſs of moiſture is carried off by a proper diſpoſition of the furrows, according to the natural deſcent of the ground, by which the water will have an eaſy paſſage to get away. It is likewiſe material that the furrows ſhould be ſtraight: for the ſtraighter the furrow, the ſhorter time will

the

the water remain in the ground. It would appear likewiſe, that the narrower the ridges were made, provided they were above the ſtagnating water, the ſooner would the water fall through them, to get at the furrow. The furrow ſhould be made with a double mouldebread plough, that both its ſides may ſlope. Marling the ground, as I ſaid before, makes it drier, by opening and looſening the ſoil. A field manured in this way, will be fit fourteen days ſooner in the ſpring for ploughing. If theſe methods do not ſuceeed, on account of water ariſing from ſprings, open or hollow drains muſt be made at different diſtances. Open drains ſeems beſt, if the ſprings be not too many.

SECT. III.

Of rains.

GREAT rains are conſiderable impediments to the proper concoction of the juices in the veſſels of plants, and alter very

very much the nature of theſe juices. Says a *French* author: *En l' année* 1705, *il ne plu preſque pas en Juin et en Juillet, et les bleds etoient excellent. Mais en* 1707, *quoiqu'il y ait eu de chaleurs extraordinaires, il plu ſi abondamment pendent les deux mois, que le blés n'ont rien valu, et ces ſont preſque tout échauffés.*

It is obſerved, that all plants grow very faſt after rains; not only the terreſtrial, but the aquatic. The latter can never be ſuppoſed to want water; ſo that this effect muſt proceed from ſome other cauſe, than the increaſe of nouriſhment by the roots. The ſame effect is obſerved to happen, when the ſky, from being clear, grows cloudy and ſtormy. Perhaps their too great perſpiration may be ſtopped: perhaps the moiſture is ſucked up by the pores of the leaves and wood: perhaps, as their nouriſhment depends on the circulation of their juices, and that circulation on the contraction of the *tracheæ* or air-veſſels, according

to

to *Malpighius*, the ſudden contraction fills the ſmalleſt and remoteſt veſſels with nouriſhing juices; and does it with ſome force, which may lengthen the veſſels. As the veſſels are more full of water, and the perſpiration leſs than ordinary, it is no wonder that the juices are not well concocted, and the grain bad.

SECT. IV.

Of faulty ſeed.

HAVING conſidered the impediments to vegetation which ariſe from the ground, let us next take a ſhort view of thoſe which ariſe from the ſeed. To produce ſtrong plants, we muſt chuſe ſtrong ſeed. Grain which has been ſtarved in meagre grounds cannot thrive.

OLD grain will not grow; and therefore, farmers always chuſe the laſt year's corn. It is thought that grain will not grow

grow when it paſſes the age of five years: but the time cannot be preciſely fixed, for that muſt depend on the drineſs and oilineſs of the ſeeds. All the oily ſeeds keep long, ſome of which will lie in the earth for fifteen or twenty years. Two months after the great fire in *London* there appeared a great crop of a ſpecies of *eryſimum*, where there had been houſes for a thouſand years. Mr. *Reaumur* ſowed ſome of the grain which had been preſerved in the citadel of *Metz* for one hundred and thirty years; and which made very good bread. In three weeks ſome of the grains were ſwelled, and ſome not. In ſix weeks no grains were to be found.

The cauſe of ſterility in old grains ſeems to conſiſt in the veſſels loſing that ſuppleneſs which is neceſſary for their extenſion, and filling with water; and in the contained liquor loſing that gluineſs which is neceſſary for nutrition. This appears from the brittleneſs of the grain, which becomes

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ſo by the evaporation of the mucilaginous parts.

SECT. V.

Diſeaſes of plants.

ALL organized bodies, conſiſting of containing veſſels, and contained fluids in motion, are ſubject to have thoſe fluids altered, and that motion vitiated. Hence the diſeaſes of plants. *Tournefort* has, therefore, judiciouſly claſſed theſe diſeaſes into thoſe which ariſe, 1. from too great an abundance of juice; 2. from too little; 3. from its bad qualities; 4. from its unequal diſtribution; 5. from external accidents.

Too great abundance of juices muſt cauſe ſtagnations, corruptions, too great a quantity of water-ſhoots, varices, carioſities, *&c.* It ſeems to be in this way that too much rain operates. The ſmut, which is a corruption of the grain, ought to be claſſed

 here;

here; because it happens moſt to weak grain, and in rainy ſeaſons. It may, likewiſe, be communicated by infection, if I may ſo ſpeak; and the ſmut, like other contagious diſeaſes, may be tranſmitted from the infected to the healthful grain. The experiment, I was informed, has been tried. Some ſmutty grain was ſown along with very good ſeed; and the produce appeared very ſmutty. Nor ought it to ſurprize us, that this ſhould happen to the juices of plants, when we find, by daily experience, that the juices of animals aſſume the nature of the contagious ferment communicated to them. This diſeaſe is prevented, in a great meaſure, by ſteeping the grain in a pickle of ſea-ſalt. This operates in two ways. It ſtrengthens the ſeed, and fits it for expelling the ſuperabundant watry juices; and, by its great weight, ſuſpends all the faulty grain; ſo that none but the heavieſt and ſtrongeſt fall to the bottom, and are made uſe of.

Dung seems to prevent other diseases arising from too great a quantity of moisture. An experiment, performed by a gentleman of my acquaintance, will show this effect of dung in a strong light. He fallowed two acres of poor ground, which had never got any manure, with a design to sow wheat on it; but altering his scheme afterwards, he laid some dung on a small part of it, and sowed the whole, after it had got five furrows, with barley. A great quantity of rain fell. The barley, on that part which was dunged, was very good; but what was on the rest of the field turned yellow after the rains, and when ripe, was not worth the expence of reaping. This experiment shows, that the moisture and poverty of the soil was the cause, and that the dung was the cure of this disease.

Plants and trees certainly decay for want of proper nourishment. This is the cause why the leaves fall off at the approach of winter. It appears plainly from the following experiment. Ingraft an almond tree on the black damaſk plumb: for the firſt year the almond tree thrives very well; but after that they both decay ſlowly and die. The reaſon is, becauſe the former vegetates much ſooner than the latter; and, therefore, requires nouriſhing juice when the former has it not. While young, it is eaſily ſupplied; but when it grows larger, it exhauſts the plumb, and is ſtarved itſelf. If the plumb is ingrafted on the almond, the juice riſes in the latter, when the former is not fitted to receive it, and it dies of repletion.

DU HAMEL, in *Mem. acad. des ſciences* for the year 1728, mentions a diſeaſe, called *le mort*, which attacks the ſaffron in the ſpring; and is owing to a plant of the ſpecies of trefoils, that has no ſtem, fixing ſome violet-coloured threads, which are its roots, to the roots of the ſaffron, and ſucking out its juice. This diſeaſe is prevented by digging a trench, which

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ſaves all the unaffected. All diſeaſes from defect of nouriſhment, are cured by the application of manures.

The juices may be, likewiſe, faulty from their bad quality. When the turpentine juices of the pine and fir turn too thick, the tree is ſuffocated. Sugar canes, it is ſaid, do not thrive ſo well in rich new ſoil, becauſe it affords too oily a juice, which is not ſo good for ſugar: if they are cut when ſix months old, the leaves burnt, and the aſhes laid round them, they afford better ſugar. The alkaline ſalt, from the aſhes of the leaves, attenuates the oils, and makes a better ſaccharine juice. Plants or ſeeds tranſported from warmer countries to cold, decay gradually, becauſe the juices are not ſufficiently attenuated for want of heat.

The unequal diſtribution of the juices ſeems to be another cauſe of vegetable diſeaſes. In corn, the juice ſometimes runs too much to the leaves; cutting or eating the corn is a remedy for this, as it ſends the juice to the ſtalk.

External accidents, ſuch as froſt, hail, flies and their eggs, vermin, &c. give riſe to many diſeaſes. There is a ſmall white hard worm very common in new ground, which deſtroys plants by eating their roots. Theſe worms are killed by quick-lime or lime-water.

The mildew is to be ranked here, as it ſeems to be owing to a gluy ſaccharine matter falling with a ſummer ſhower, and blocking up the perſpiration of the plant. This matter may be felt and taſted on the ſurface of the leaves. That it operates in this way, appears from the following fact. There is in the *Briançon*, a ſpecies of nut-tree, which has all its leaves covered with a ſaccharine ſubſtance, ariſing from the perſpiration of the juices of the plant. If it is in very great quantity, the trees often die.

Amongst

Amongst the claſs of external accidents we may place the effects which ariſe from the contiguity of certain plants. There are ſome plants which do not thrive in the neighbourhood of others. This is obſerved of the cabbage and cyclamens, of hemlock and rue, of reeds and fern. We have many examples of ſuch like antipathies amongſt animals. Theſe effects ſeem to be produced by the effluvia which are emitted by all organiſed bodies.

It is ſurpriſing that the preſent ſubject, ſo highly neceſſary to the proper culture of plants, ſhould have been almoſt entirely neglected; ſo that an inquirer finds too few facts and obſervations to be able to lay down any regular ſyſtem. Beſides, the diſeaſes of vegetables ſeem to require more aſſiſtance, and therefore demand more attention, than thoſe of animals; if we regard the cure alone, and ſet aſide the higher rank in the ſcale of creation, and conſequently the higher value of the latter. Animals have a ſentient power within, which, irritated by the cauſe of a diſeaſe, quickens the motions of the heart and arteries, and continues theſe mechanical agents till the morbific particles are expelled, or the animal ſyſtem overpowered by them. But there is no ſuch power inherent in vegetables. Unleſs a remedy is applied from without, they muſt continue to labour under the diſeaſe. Whoever removes the diſeaſe of an animal, does it by directing theſe natural and mechanical motions aright, and in the way that the motive power ſeems to point out. But whoever removes a vegetable diſeaſe, muſt look on the work as entirely his own, as he has got no aſſiſtance from the vegetable itſelf.

SECT.

S E C T. VI.

Plan for the further improvement of agriculture.

THUS I have endeavoured to ſhow, that agriculture is not ſo uncertain and unſcientifical an art as is commonly thought; but is reducible, like other arts, to fixed unalterable principles. I have already looked back, and conſidered the impediments which have lain in the way of its progreſs to ſome degree of perfection. I ſhall now look forward to ſee how theſe may be beſt remedied, and in what manner we can aſſiſt it in its progreſs.

AGRICULTURE does not take its riſe originally from reaſon, but from fact and experience. It is a branch of natural philoſophy, and can only be improved from the knowledge of facts, as they happen in nature. It is by attending to theſe facts that the other branches of natural philo-

ſophy

ſophy have been ſo much advanced during theſe two laſt ages. Medicine has attained its preſent perfection only from the hiſtory of diſeaſes and caſes delivered down. Chymiſtry is now reduced to a regular ſyſtem, by the means of experiments made either by chance or deſign. But where are the experiments in agriculture to anſwer this purpoſe? When I look round for ſuch, I can find few or none *. There, then, lies the impediment in the way of agriculture. Books in that art we are not deficient in; but the book which we want is a book of experiments.

And, indeed, as things ſtand at preſent, it muſt always be ſo. Mankind are ſhy in attempting any thing, or at leaſt render-

* Since theſe papers were wrote, I have read three volumes of experiments publiſhed by *Du Hamel*, on *Tull's* ſyſtem of agriculture. They are diſtinct, exact, concluſive, ſo far as they have gone, and ſtand a model for experiments in agriculture. What a ſhame for *Great-Britain*, where agriculture is ſo much cultivated, and where that ſyſtem took its riſe, to leave its exact value to be determined by foreigners!

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ing it public, unless they can make it complete, or erect some plausible system. This they may do in all other arts, but they cannot in agriculture. The time so seldom comes about, and the progress of the experiment is so slow, that one person can make but very few during his life. A number of experiments are to be found, not in the possession of one, but in the hands of many. The fault, then, lies not in the deficiency of facts; for chance and design must have been able to furnish many; but of a certain, proper, and easy channel, through which they might be conveyed to the world, without wounding the natural vanity of mankind.

Hitherto these facts and experiments have been confined to conversation alone, and have died along with those who made them. I would propose a simple remedy for this. Let a committee of the *Edinburgh* society, not exceeding five persons, be named for the branch of agriculture

alone,

alone, whoſe duty ſhall be, to receive ſingle and detached experiments, put them in a proper dreſs, if they ſtand in need of it, and publiſh them to the world at ſtated times, like a public paper. This manner of appearing ſeems well calculated to raiſe a ſpirit of experimental farming over the country.

The narrator, on his part, ſhould deliver the experiment in the plaineſt and moſt diſtinct manner, and ſeparate the facts from his reaſonings. Perſpicuity and exactneſs are the chief beauties in experimental writing. The plain fact ſhould be firſt told, with all its concomitant circumſtances; ſuch as, the ſituation of the ground, nature of the ſoil, previous culture of it, quality of the ſeed, country where the experiment is made, ſtate of the air, at ſowing and after, with regard to heat and cold, drought and rain, wind, &c. The reaſoning on the experiment ſhould then follow, and ſhould be ſuch as arises naturally from the experiment. Although it is not necessary to mention any name to the public, yet the experiment, when delivered, should be subscribed by the person who made it, to avoid all imposition.

In order to increase the spirit of experiment-making over the country, I would propose, that this committee should have it in their power, to grant one or more honorary or lucrative premiums, to those who shall have delivered the most ingenious and useful experiments in agriculture. It is in this way, I think, that the premiums designed for agriculture should be established. They ought to be, not on such subjects as the farmer is naturally led by his own gain to pursue; for such he will generally follow, to the utmost of his knowledge and abilities; but on such as are not so nearly connected with gain, and make him go out of the common road. This confinement may, however, be too great

great at the firſt ſetting out; and it may be more adviſable, to admit all experiments for ſome time, till the ſpirit be once raiſed.

The happy conſequences of this ſcheme are very evident. Farmers will begin to ſee the only method of cultivating this art with ſucceſs; they will attend to minute circumſtances to which they never did before; they will be fond to communicate the iſſue of their experiments to the public, when they can do it in that eaſy and concealed way; they will have a dictionary of facts to conſult opon occaſion; and will be able to draw advantage from both the good and bad ſucceſs of others.

In time this plan may afford fund ſufficient for ſome future comprehenſive genius, who, laying the different, and often ſeemingly oppoſite experiments together, and conſidering all their concomitant circumſtances, may be able to reduce the practice

to

to fixed and permanent rules. This good fortune ſeldom happens to the firſt experimenters in any art; for they ſee things in too narrow a view, and often with too prepoſſeſſed a mind. It is reſerved for that unbiaſſed and ſound judgment, which can take from every opinion whatever truth it contains; and, from the whole united together, raiſe one regular, beneficial, and laſting ſyſtem.

F I N I S.